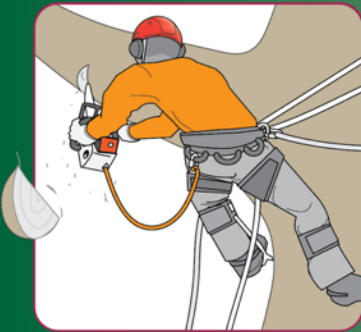




TREE DISMANTLING

TECHNIQUES FOR RIGGING AND
AERIAL TREE REMOVAL OPERATIONS

MIS303



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This document is based in part on material created by Scott Sharpe in 2008 to 2010. This project was something he often discussed. The loss of his knowledge and enthusiasm is strongly felt.

The Minimum Industry Standard series is dedicated to all our fellow workers who have lost their lives or have been permanently injured working in the arboriculture and vegetation management industries.

A Minimum Industry Standard for tree support systems

This book is one in a series of Minimum Industry Standards produced by Arboriculture Australia Ltd and the New Zealand Arboricultural Association in consultation with the national arboriculture community in both countries. These industry peer-reviewed documents provide a 'body of knowledge' which is shared by practitioners and can be used as the basis for training, dissemination of skills and professional development.

This standard covers the basics of tree dismantling, including rigging techniques, the use of a chainsaw in trees, and some fundamental concepts of rigging forces and rigging system design.

Information on equipment inspection, site setup, pre-start checks, tree inspection, rope use, knot tying, the operation of chainsaws, tree felling and tree access is contained within the appropriate MISs for those work tasks.

Industry partners

The Minimum Industry Standard series was produced by Arboriculture Australia Ltd and the New Zealand Arboricultural Association in partnership with the following state and national industry bodies. The document bears their logos as a mark of ratification.



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How to use this Minimum Industry Standard

This Minimum Industry Standard (MIS) is written to establish and record industry consensus on tree rigging and dismantling. Whilst it can be used to support training, this MIS is not intended to replace formal training and qualification in the work tasks which will be conducted.

This standard is organised in the following sections:

Preparing for tree removal	Discusses removal strategies, selecting and inspecting rigging equipment, basic concepts of tree dismantling, terminology, site setup and management. Includes general principles of rigging system design, how to attach and configure rigging system components, how to estimate weights of pieces and an introduction to forces in tree rigging.
Dismantling trees	Covers chainsaw use in trees, dismantling operations and techniques. Gives examples of different cut sequences to achieve required results. Provides an overview of principles for good rigging practice, which will be common across most different rigging systems.
Completing tree removal	Discusses equipment retrieval, equipment retirement or storage, site clean-up and completing dismantling operations.
Appendix A: Rigging system diagrams	Gives examples of how to configure rigging equipment into different systems in order to achieve particular rigging objectives.
Appendix B: Working the angles	Discusses the mathematics and physics behind rigging operations. This section can be used as a reference for further consideration of some of the points discussed elsewhere in this MIS.

Other applicable standards

This MIS does not discuss PPE inspection, tree inspection, preparing for specific tree work, site setup, tree access techniques, tying knots, or emergency or rescue preparation.

The use of cranes for dismantling is discussed in the crane-specific MIS below.

The following MISs are considered to apply to some or all of the skills and techniques described in this document:

Minimum Industry Standard	Example content which may apply to tasks described in this document
MIS300 Safe Tree Work	Safe work framework, PPE selection and use, risk management, site setup and management, scope of works, clean-up, inspection and care of equipment.
MIS301 Arborist Knots	Selection and use of appropriate knots for access and rigging.
MIS302 Arborist Ropes	Selection, inspection and use of ropes for access and rigging.
MIS304 Aerial Rescue	Preparation for and undertaking of aerial rescue.
MIS305 Tree Climbing	Tree climbing for access during dismantling.
MIS306 Tree Inspection for Access and Work	Identification of tree defects and hazards which may require altered work plans of other control measures; risk management.
MIS307 Crane Use in Tree Work	All aspects of crane selection and use for dismantling operations.
MIS309 Equipment Inspection	Periodic documented inspection of PPE, height-safety and rigging equipment.
MIS311 Stump Grinding	Specific to the post-dismantling removal of the stump.
MIS315 Chainsaw Operations	On-ground and aerial use of chainsaws; chainsaw maintenance; cutting techniques.

1: Preparing for tree removal

Introduction to tree rigging and dismantling

Tree dismantling is the process of removing trees by accessing their aerial structure to cut or rig pieces from the tree in order to remove it in stages. Trees that are dismantled are usually in confined spaces, or surrounded by other plants or garden beds, so that it is impractical to fall the tree from the ground.

Arborists use elevating work platforms (EWPs), cranes, climbing and rigging equipment, and chainsaws to **free-fall** or **rig** sections out of trees, ensuring that each piece is controlled to land in a lowering or drop zone.

Rigging is defined in arboriculture as a method of using ropes and hardware [...] in tree pruning or removal, to control or direct the descent of cut material or to handle heavy loads.¹

Arborists use rigging techniques to lower heavy branches over fragile gardens, swing timber away from a house, lift extended limbs clear of rooflines, zipline logwood across to a wood chipper, and control the direction of falling tree parts.

Safe and effective tree dismantling must include:

- ☐ Putting safety first.
- ☐ Having a professional attitude, taking care and pride in the work that is conducted.
- ☐ Careful and methodical forward planning and risk assessment.
- ☐ Having a 'mental tool kit' of different possible rigging techniques, removal strategies and setups.
- ☐ Having the knowledge to determine the strengths and weaknesses of different rigging systems.
- ☐ Recognising the limitations imposed by tree structure, crew size and ability, access to equipment, and own experience and skill level.
- ☐ Selecting a suitable dismantling process for each piece.
- ☐ Implementing the chosen process, including communicating with crew, adjusting piece size to processing capacity, correctly tying knots and making accurate cuts to control the movement of tree parts during rigging operations.

While this MIS will discuss many of these techniques and skills, there is no substitute for or shortcut to experience.

Tree dismantling is a skill that may take decades to master. Novice tree workers should focus on mastering fundamental skills and simple rigging systems before attempting complex tree rigging without supervision.

Arriving on site

Scope of works

Before arriving on any job site it is important for the team to be clear about what work has been specified, and how it will be done.

This will help to make sure that the correct tools and equipment are prepared for the work that will be conducted, and allow enough time to complete the prescribed works. In many organisations work instructions are given in the form of **specifications** or **scope of works**.



These can be provided as paper documents or on tablets or via other electronic means. Regardless of they are provided, it is critical for workers to receive all of the required information. The scope of works should include:

Which trees are to be removed?

- These should be clearly identified, preferably including a site map if there are multiple trees on site. If there is any doubt, clarification must be sought.

What is to be done with the debris?

- Will branches be mulched?
- Will mulch be left on site or removed? If left on site, where should it be tipped or sprayed?
- Will timber be removed or left on site? If left on site, where should it be left? Does it need to be cut to particular lengths? Should it be split or stacked?

What height should the tree be left at?

- In most cases, trees will be removed to ground level but if the stumps are to be removed with an excavator or similar at a later date then a metre or more of stump should be left to give leverage.

Does the stump need to be ground out or otherwise removed?

How much care should be taken of garden and other surrounds?

- This is a very important point to confirm, particularly when quoting work. Being able to drop sections into a garden – or not – can make hours of difference to even a small tree removal. If possible, this should be explained to clients when quoting work to confirm where gardens must be protected.

What times and dates are suitable for tree work to be conducted?

- Tree work is noisy, and tree work sites and machinery will usually prevent access. Ensure that approval has been obtained for the work to proceed!

Any other notes:

- Are there underground services or septic tanks?
- Any known habitat or environmental considerations?
- Any considerations of access, gates, pets etc.?
- Any tree protection permits that apply? Is the tree listed as significant, or under a heritage or vegetation protection overlay?
- Many councils and municipalities have unique enforced bylaws when it comes to protection measures removal of trees on private land

If possible, **the scope of works should be discussed with the client** before beginning tree removal. All elements must be understood agreed before work commences.

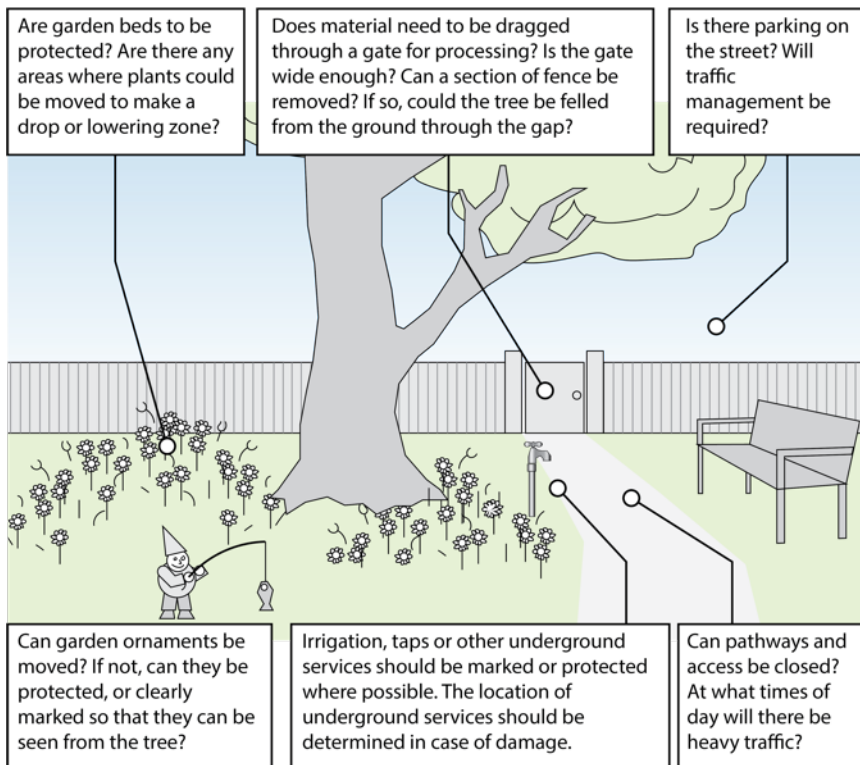
The scope of works can be reviewed with all crew members on site to confirm that specified work is clear and understood.

Preparing to remove trees – site setup

The process of preparing to conduct tree work, site setup, conducting a site-specific job safety analysis (JSA) or safe work method statement (SWMS), implementing emergency preparations and preparation for rescue are discussed in:

- **MIS300 Safe Tree Work**
- **MIS304 Aerial Rescue**
- **MIS306 Tree Inspection for Access and Work.**

When preparing to remove trees some additional site setup may be required. Where possible, any obstacles and trip hazards should be removed, plants or structures that may be damaged should be moved or marked, and drop zones, lowering zones and processing areas should be cleared of any impediments.

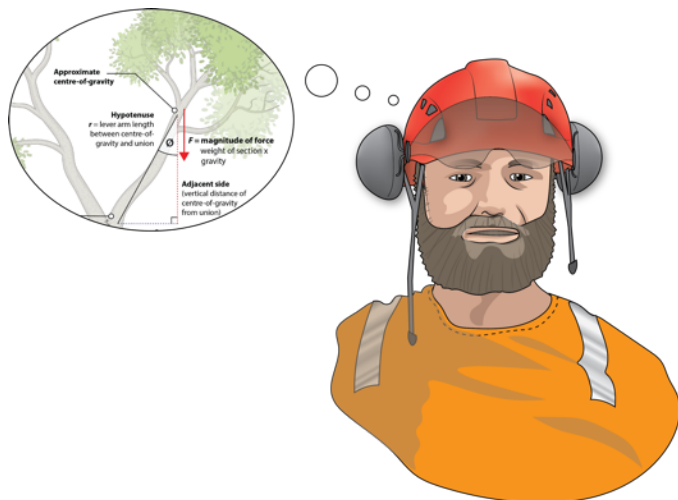


Tree removal strategies

A tree removal strategy describes the whole collection of techniques, processes and work practices that will be combined in the correct sequence to remove the tree. This can include:

- Falling the tree.
- Dismantling the tree by cutting and free-falling pieces.
- Dismantling the tree by rigging pieces.

Most tree removals will use a mixture of these techniques, each applied at different stages of the removal.



Selecting a simple, efficient and safe strategy is the first challenge of good tree removal: arborists must take the time to consider and investigate all possibilities, inspect for hazards and adjust the work plan as needed. Ensure that all crew members participate in discussions:

- They may spot hazards that the crew leader has missed.
- They may suggest alternative strategies.
- Collaborative planning and discussion means that everyone will be 'on the same page' for the work to come.

Each tree is different and may require different strategies. A good crew leader is adaptable and will listen to input from other members of the crew.



If we could remove a section of fence, we could fall the tree from the ground

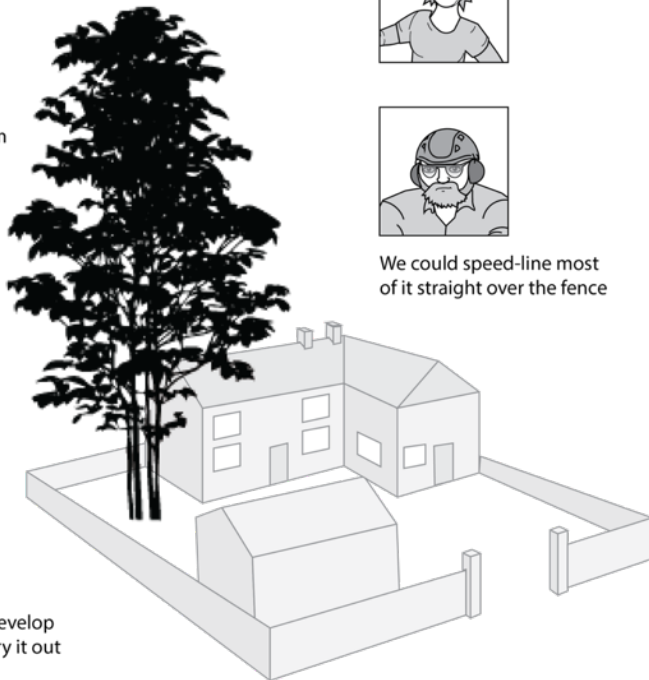
Establishing a high rigging point would let us rig the foliage right to the chipper

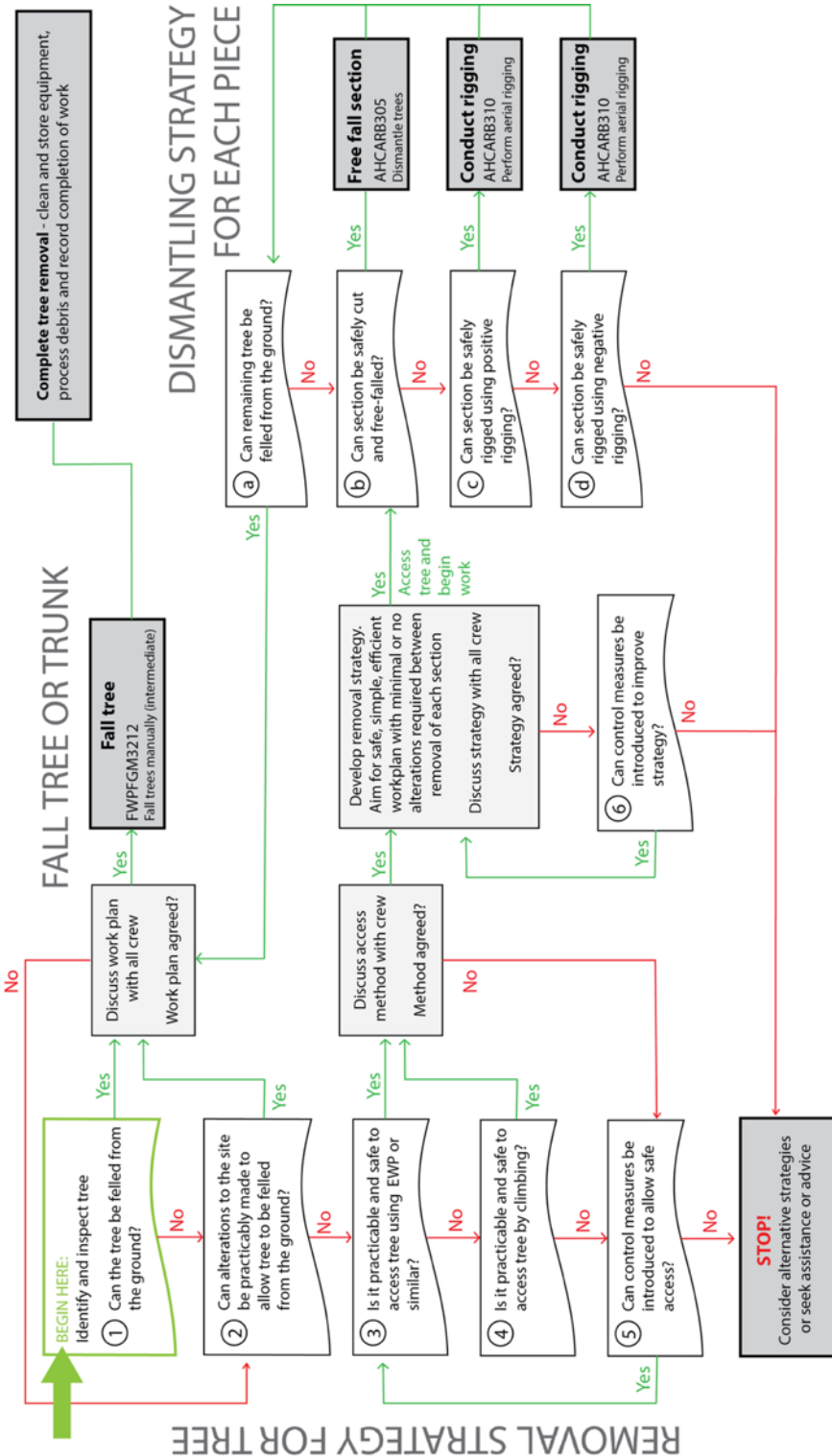


We could speed-line most of it straight over the fence



Let's keep this simple. Start at the bottom, develop a good work flow, carry it out in small pieces.





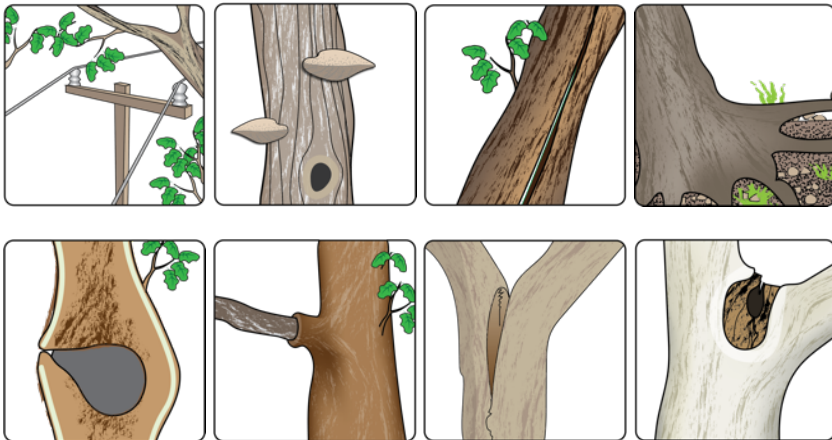
Tree inspection for dismantling

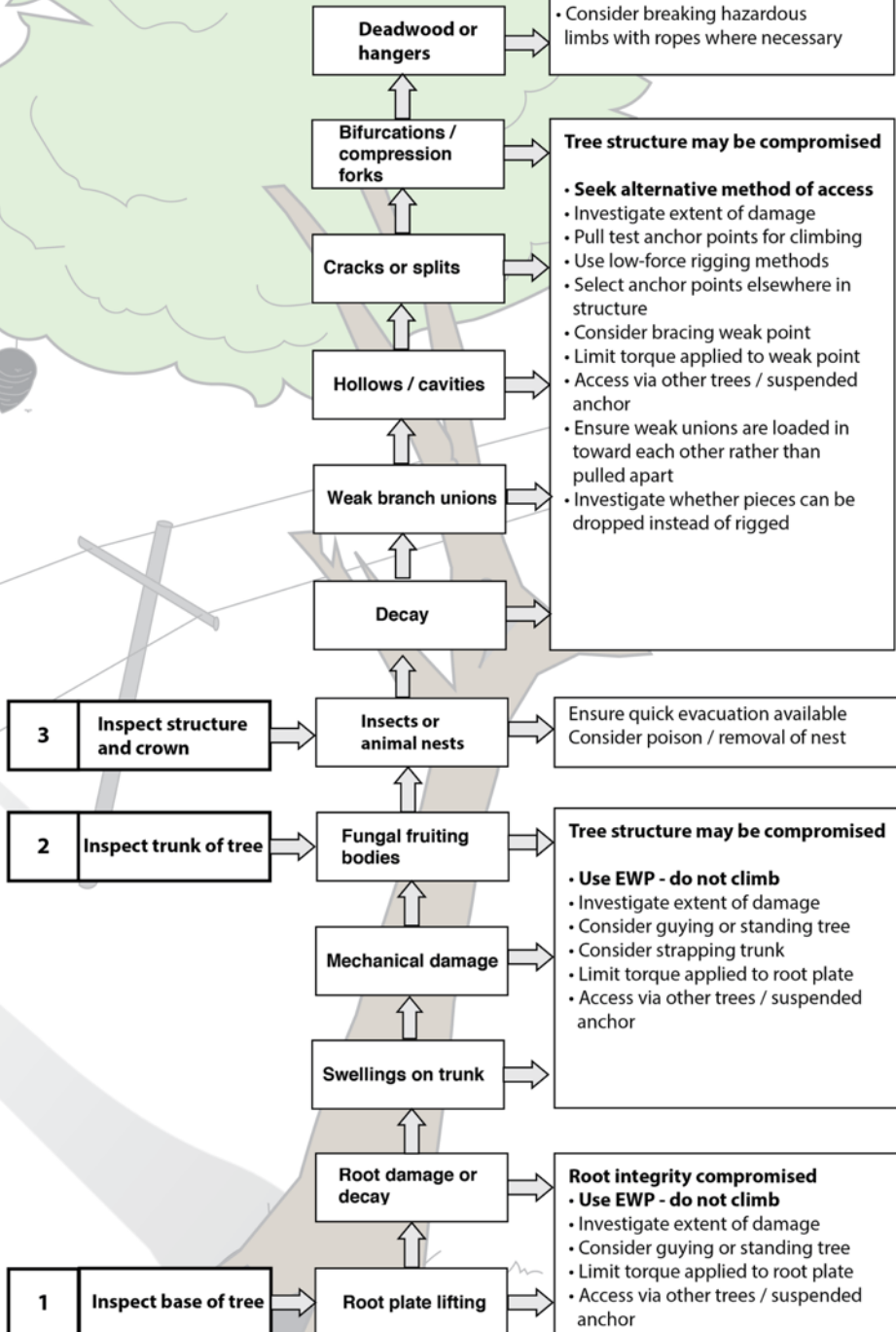
Tree inspection is discussed in depth in:

MIS306 Inspect Trees for Access and Work.

Extra care should be taken when dismantling trees as **significant forces can be applied to tree structures during rigging and dismantling operations**. Even felling sections out of trees can apply large lateral forces and has sometimes resulted in root plate failure and worker fatalities.

A methodical, thorough tree inspection must be conducted. All crew members on site must be included in the discussion.





Hazard control measures for tree dismantling

If tree inspection identifies any hazards, the removal strategy must be adjusted control or eliminate any risk. In the examples below, control measures are shown marked as:

- **strong control measure.** Select green controls where practicable.
- **strong control measure,** with some considerations. For use by experienced operators.
- only for **specific use** by experienced operators. Possible significant residual hazards.

Examples of possible control measures³ include:

1. Remove the tree without climbing the tree by:

- **Falling the tree from the ground** if possible. If necessary, significant preparation works or subsequent damage control or repair may be required. In many cases this is both safer and more cost effective. Consider whether fences can be removed, garden plants temporarily transplanted or replaced, and other structures relocated or protected.
- **Using aerial lifts and EWP**s if possible. Many of the hazards associated with climbing may remain but for some trees and sites significant improvements in safety could be made by the use of EWP's. For some sites (limited access or setup space) the use of EWP's may be more dangerous than climbing.
- **Conducting crane removal** if possible. The use of cranes may significantly reduce or completely eliminate the magnitude of forces that rigging operations might apply to compromised tree structure. Ensure that all tree workers are trained and experienced in the use of cranes for tree work before conducting crane removal operations.
- **Working from adjacent trees** if possible. While this may be a strong control measure in some instances, in most cases workers will still be at significant risk were any part of the compromised tree to fail. Workers may still need to attach to the compromised tree to achieve a secure work position. See **MIS305 Tree Climbing**.

2. Support compromised tree structure by:

- **Cinching up the trunk with ratchet straps** or chains, in order to prevent splitting. Supporting a split trunk or branch in this manner may achieve significant improvements in trunk integrity but should only be used by experienced workers with a good understanding of the application and limitations of use.
- **Bolting** split crotches to stop crack propagation. Again, techniques such as this to work allow access and work in severely compromised trees should only be used by experienced workers who recognise the limitations of these control measures.
- Loading crotches with included bark in compression only.
- **Guying the tree to the ground or to adjacent trees**, in order to dissipate peak loads and prevent stem fracture and/or tipping failure. While guying can offer critical support to compromised trees, the guys themselves can also present a new hazard – contact between dropped or rigged pieces and guy ropes can generate enormous forces, and guy ropes should only be used by very experienced operators. See page 166, Guying a tree.

3. Reduce loads generated in rigging operations by:

- Cutting shorter sections, reducing peak load.
- **Using specific rigging techniques** to reduce magnitude or improve direction of resulting force vectors.
- **Retaining lower stem foliage**, retaining mass dampening during rigging operations.

4. Seeking further assistance or alternative strategies:

Many trees exist that cannot be accessed to dismantle by even the most technically accomplished and experienced tree workers. Recognising the limits of competence and seeking assistance is one of the most challenging aspects of tree work – and failure to do so results in many fatalities.

- **Seek assistance from a more experienced operator.** Watching how they go about working with the compromised tree can offer an excellent opportunity to develop skills and knowledge. Cutting and hoping for the best may work the first time – but nothing useful will be learned, and workers may be badly hurt.
- **Record that dismantling is not possible and seek alternative strategies.** If hazards exist that cannot be eliminated or controlled, tree dismantling operations may not be possible. Record that dismantling was not possible along with the reasons why and seek alternative strategies. For example, clients may elect to prevent access to the tree area, move targets, or replace or relocate structures to allow the tree to fall naturally or to be felled from the ground at a later date. Sometimes compromise needs to be made between the client and the tree worker to keep risk within an accepted level.

List of control measures adapted by author from Health and Safety Executive, UK *Evaluation of Current Rigging and Dismantling Practices used in Arboriculture* (2008).

Basic rigging concepts

As discussed earlier in this document, **rigging** is defined in arboriculture as a method of using ropes and hardware [...] in tree pruning or removal, to control or direct the descent of cut material or to handle heavy loads¹.

In most rigging systems, a load is **held**, **lowered** or **lifted** with a rope. That rope is supported at an **anchor point** or anchor points in the same or adjacent tree, or in another structure. At some point in the system, sufficient **friction** is applied to the rope to allow a crew member to control the rigging operation by managing the tension in the rope by hand.

The practice of aerial rigging consists of:

- Recognising the requirement for aerial rigging to take place in order to achieve a tree work objective.
- Designing a rigging system that will allow the required work to be conducted in a safe and efficient manner.
- Conducting aerial rigging.
- Completing aerial rigging and retrieving equipment.

Most aerial rigging takes place where:

- Tree parts that must be cut cannot be dropped due to target/s underneath; or
- Tree parts could be dropped but it is safer or more efficient to lower those parts; or
- Tree parts must be lifted, swung, drifted or moved prior to being dropped or lowered; or
- Tree parts are to be processed in a particular area and it is safer or more efficient to rig those parts directly to that area rather than to drop or lower parts where they are.

Parts of an aerial rigging system

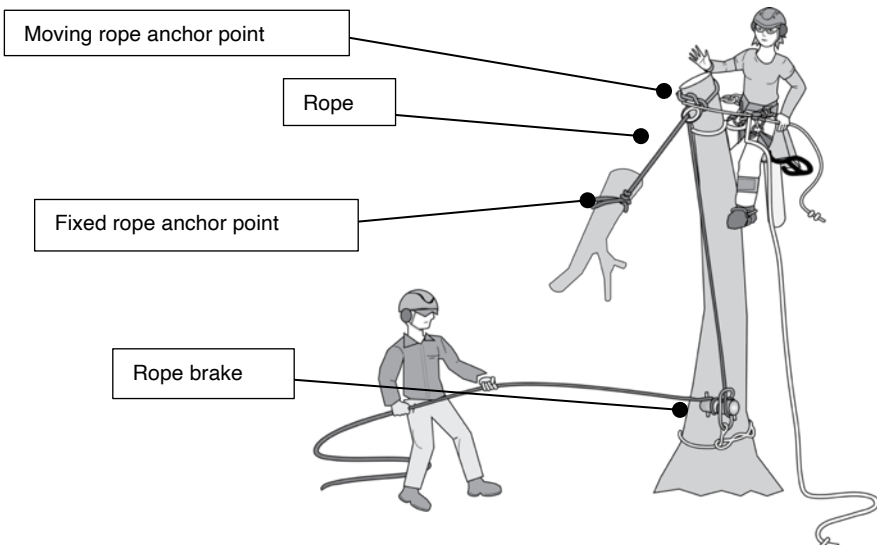
In order to conduct aerial rigging, an anchor point is selected. By passing a rope over this anchor point and attaching it to a branch, the branch can be cut from the tree and then lowered with the rope. The anchor point can be the union of a tree, a point in a different tree, or an artificial anchor point such as a pulley, block or rigging ring.

If the rope is moving across the anchor point, rather than tied off or secured, it is called a **moving rope anchor point**. Moving rope anchor points can be **natural crotches** (unions or similar in the tree) or **artificial crotches** – pulleys, rings, rigging blocks or similar through which the rope can be installed.

If the rope is secured to the anchor point (for example tied or attached to part of a tree), it is described as a **fixed rope anchor point**.

For larger branches or sections of timber, additional **friction** may be required in order for the load to be controlled. **Friction** is applied to rigging systems either by taking wraps of rope around a tree part, or by using an artificial device such as a Portawrap or Figure-8. In either case, the place where friction is applied is described as a **rope brake**.

The addition of friction will mean that even heavy loads can be controlled easily by hand. The rope can be held tight in order to support or suspend cut pieces, or allowed to run in order to lower the piece, as required.



Selecting and inspecting rigging equipment

Selecting and inspecting rigging equipment requires good knowledge of equipment ratings, intended rigging usage and compatibility. Proper inspection of all tree climbing equipment is an essential part of safe tree work. The unexpected failure of rigging equipment components may result in serious injury or damage, so rigging equipment inspection should be conducted with the same thoroughness as the inspection of life support equipment.

Equipment inspection should be conducted in two ways:

- 1 By a qualified trained third party, as part of a regular documented inspection regime. See **MIS309 Equipment Inspection** for more details.
- 2 Before each use, by the worker who will be using the equipment or a qualified supervisor.

Regular documented equipment inspection is a requirement for tree work in both Australia and New Zealand². Ensure that periodic inspection is thorough, documented and regular. Ensure that where equipment is identified as unsafe, or has reached the end of its service life, that it is immediately recorded as such and retired.

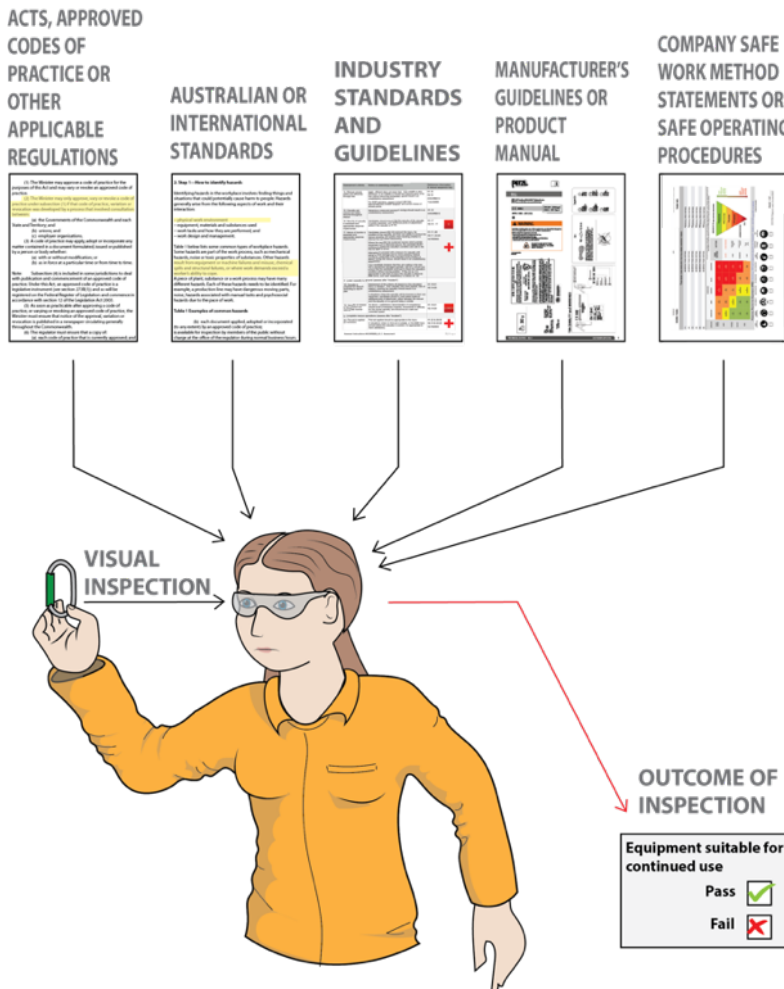
What is the service life of my equipment?

Most equipment will be produced with a manufacturer-recommended service life detailed in the product manual. This recommended service life can vary significantly, even between two very similar pieces of equipment – always check the manual or contact the manufacturer! Ensure that you record when equipment is purchased and enters service – this will allow you to retire the equipment after an appropriate period.

Harsh conditions and strong ultraviolet radiation can rapidly degrade plastics and synthetic textiles. Always consider the recommended service life to be a maximum limit rather than a minimum! A lot of equipment will need to be retired long before its recommended service life has expired.

Who should I get to inspect my equipment?

Accessing regular qualified equipment inspection may be challenging for some operators. At a minimum, ensure that another trained and qualified worker conducts a thorough and documented check of all climbing equipment at least once every six months. If possible, try to find a third party from outside the business to conduct this inspection – they are less likely to be users of the equipment and more likely to conduct a thorough inspection.



Rigging equipment: general concepts and terminology

The following concepts and terminology may assist in both identifying appropriate equipment for particular rigging operations, as well as conducting regular and pre-work inspections. For further rigging terminology and a glossary of terms, please see the general glossary on page 205.

Abrasion resistance

(of rope)

Selecting cordage that is suitable for intended use is critical. Please see **MIS302 Arborist Ropes** for more details.

Axis or axes

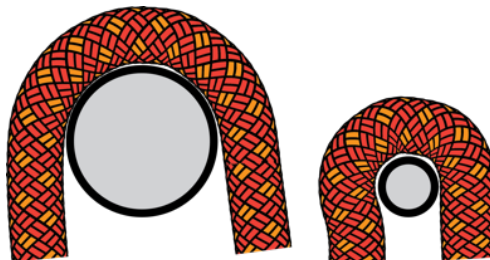
(of loading)

Some devices (rigging rings, rigging plates, etc.) can be loaded in many different axes. Others (karabiners, some friction brakes, pulleys) are only designed to be loaded along one axis. See page 51 (Rigging equipment configuration) for more details.

Bend ratio or

Bend radius

When a rope is bent over a point, the outer part of the rope must cover more distance than the inner part, so is 'stretched' and carries a greater share of the load. As can be seen in the image below, the tighter the radius of the bend the more disparity there will be in the two parts of the rope, and the more that the rope will be weakened as a result.



Configuration The correct connection of the component to other parts of the rigging system, or the manner in which it should be used or loaded. Knowing the correct configuration of the equipment that is being used is a critical component of rigging system design.

Cycles to failure Cycles to failure is defined as the 'Number of times a rope or other piece of equipment can be used with a given load before mechanical failure'.

Applying greater loads to rigging components will reduce the number of operations in which those components can be used before failing.

Design factor or
Safety factor The design factor or safety factor is the ratio of minimum breaking strength (MBS) to working load limit (WLL). The relationship between these three parameters means that, provided any two of them are given, the third can be calculated.

Some manufacturers will provide just MBS or WLL; in these case an assumed safety factor of 10:1 (for most equipment) can be used to estimate the other value.

Elongation or
Elastic elongation Selecting cordage that is suitable for intended use is critical. Please see **MIS302 Arborist Ropes** for more details.

(of rope)

Fall
(side of rope) The part of the rigging rope between the anchor point and the ground or between the anchor point and subsequent anchor points. Compare with **Lead (side of rope)**.

Fixed rope anchor point	A fixed rope anchor point is where a rope is tied or secured to a tree part or other anchor.
Knotted strength (of rope or slings)	Knowing about the reduction in strength caused by knots, hitches or other bends in a rope or sling is important to assessing configured strength. Please see MIS301 Arborist Knots and MIS302 Arborist Ropes for more details.
Lead (side of rope)	The part of rope that is attached to the rigged load; between the load and the first anchor point. Compare with Fall (side of rope) .
Minimum breaking strength	MBS, also known as minimum breaking strain is usually expressed in Kilonewtons (kN), and is the minimum load above which an item of lifting equipment can be expected to fail when new and when used in the correct configuration . This number will rapidly drop, i.e. the equipment will break much sooner than expected, when using old, worn, damaged or misconfigured equipment.
Moving rope anchor point	A moving rope anchor point is part of a rigging system where a loaded rope makes an angle and can be supported but will still be able to move freely across that angle. Examples include pulleys, rigging rings, tree unions, rigging blocks.
Point of cut	The place where a cut will be made during a rigging operation – can be scarf, step cut or other.

Recommended rope diameters For some hardware such as blocks, pulleys and bollards, the manufacturer may provide a recommended range of rope diameters. This may be printed on the device (sometimes shown as ϕ) or found in the manual.

Exceeding the recommended rope diameter may result in abrasion of hardware, damage to rope, or reduction in rope strength (see bend ratio).

Rope brake A rope brake is a part of a rigging system through which a loaded rope is able to move where friction has been deliberately added to allow control over the movement of the load. Examples include wraps around a tree, Portawraps, rigging bollards.

Spliced strength
(of rope or slings) Splices can be a good way of retaining rope strength in configured systems, and are usually considerably stronger than knots but will still normally reduce the strength of a rope. For the purposes of this MIS, it will be assumed that cordage has been spliced by the manufacturer rather than the end user and that the spliced strength is available from the rope label or manual.

Working load limit The recommended WLL of a piece of equipment is the maximum recommended load it should experience when correctly configured during regular operations. This amount will be considerably lower than the MBS.

Either MBS or WLL will usually be printed on the device or available from the product guide or manual.

Rigging equipment inspection checklist

Please see **MIS302 Arborist Ropes**, **MIS305 Tree Climbing** and **MIS309 Equipment Inspection** for more details on the correct inspection of cordage and climbing equipment.

Pre-start checklist for all rigging equipment:

- ☐ Check for date of service and manufacturer's recommended service life – replace if service life is exceeded.
- ☐ Confirm cordage: rigging ropes, tag lines, slings, tape slings and textile connectors.
- ☐ Ensure that rigging lines are fit for intended purpose and are in original condition.
- ☐ Identify the rope construction used and apply that knowledge when inspecting ropes for damage (see **MIS302 Arborist Ropes**).
- ☐ Inspect lines and slings for damage such as glazed areas (heat damage), inconsistent rope diameter (internal damage), discoloration (chemical contamination), and stiffness (exposure to pine pitch) – look particularly at areas where rope wear is likely to be concentrated such as at the splice and near the working end.
- ☐ Check for cuts, puffs (pulled strands) and areas of excessive fraying (see **MIS302 Arborist Ropes**).
- ☐ Ensure that all rope ends are secured and will not unravel; consider melting, gluing, whipping or taping, depending on rope type.
- ☐ Inspect splices for correct selection and construction – determine whether splices are suitable for purpose.
- ☐ Ensure that adjustable slings (loopie sling, whoopie sling) can be moved smoothly across the full range of adjustment.
- ☐ Ensure that tape slings are tied properly using a water knot or beer knot.

- ☐ Ensure that cordage strengths are appropriate in configured rigging systems – anchor point connections in tree may experience much higher forces than rigging lines.
- ☐ Inspect all other devices according to the manufacturer's recommendations for their function, lifespan, inspection regime and storage.

Pre-start checklist for hardware: blocks, pulleys, friction brakes, connectors

- ☐ Ensure that connectors open and close smoothly and that the locking function closes completely; if karabiner gates stick or stays open, try cleaning with an air hose and lubricating.
- ☐ Ensure that connectors are free of cracks, sharp edges or excessive wear – any wear exceeding 5% of the cross-section of a device should be reason for retirement.
- ☐ Ensure that hardware is free of cracks, sharp edges or excessive wear – any wear exceeding 5% of the cross-section of a device is reason for retirement.
- ☐ Inspect for bent or disfigured components – any visible bending should result in retirement.
- ☐ Ensure that devices with moving parts (such as blocks, pulleys) function correctly and are free of stiffness or wear.
- ☐ Inspect for corrosion; ensure surfaces that will contact textiles or moving rope are free of rust and will not abrade rope .

Aerial rigging systems

Common components of a rigging system

Some common components of a rigging system are shown below and discussed on the following pages.

Component	Symbol	Description
Tree, tree part or anchor		Includes all tree structure that will be affected by or incorporated in rigging operation.
Fixed rope anchor point		Describes attachment between rope and other component – can be knot, series of knots, slings, etc.
Point of cut		The place where the cut will be made during the rigging operation – can be scarf, step cut or other.
Moving rope anchor point (no added friction)		Can be rigging block, natural crotch, or other device. Includes all attachment components.
Rope		Can be any rope that is suitable for the rigging operation (see MIS302 Arborist Ropes).
Rope brake		A bollard, Portawrap, wraps around tree or similar, where friction has been added to allow control of the load.

Selecting anchor points in trees – tree strength and structural integrity

Anchor point selection should consider:

- the position of the anchor point
- the species of tree and the behaviour of the species' timber
- the direction and magnitude of the force that will be applied to it during the planned rigging operation
- the strength and structural integrity of the anchor point, all of the supporting structure of the tree, and of any other structures incorporated within the system.



Key points for consideration when selecting anchor points:

- The failure of tree structure will normally be more likely than the failure of correctly selected rigging equipment in good condition.
- Techniques for assessing tree structure and selecting suitable access and work methods are contained within **MIS306 Inspect trees for access and work**.
- Where tree structure is of concern, techniques such as guying, bracing, using highlines, using multiple anchor systems or using adjacent trees or structures should be considered.
- Place anchor points on or near the stem to reduce leverage and select branches with a low stem-to-branch diameter ratio, unless specific torque-reducing rigging techniques are used.

Branches whose diameter is small compared to the stem may be weakly attached into just the outer layers of the trunk; do not use these as climbing or rigging anchor points.

According to the HSE *Evaluation of Current Rigging and Dismantling Practices used in Arboriculture*, published in the UK in 2008³:

The selection of an appropriate anchor point in a tree requires not only a good work plan, but also an ability to correctly assess the load-bearing capacities of tree stems and branches. Experience is the main determinant of the way in which the majority of practising arborists, in their day-to-day work, manage to choose anchor points that are usually capable of supporting the loads generated in standard rigging scenarios. Yet, many arborists underestimate the force that may be generated at an anchor point in the case of an unexpected shock loading. In general, when arborists undertake any tree climbing activities (many of which are for purposes other than rigging operations), anchor points are frequently chosen based on experience gained only in carrying out routine climbing operations under normal conditions. Such choices do not necessarily take into account the potential forces that could be generated as a result of an unexpected slip or an arrested fall.

The intentional snatching of great masses is usually only required when removing the lower portions of a tree's trunk, or sections of scaffold branches that originate from the bottom of the crown. The load bearing capacity of a solid stem is usually not critical in a tree of relatively large diameter, because the strength of a tree increases with the third power of the diameter. If the force generated in a rigging operation acts with a lever of less than 10 m, the strength of any stem above 60 cm (2 ft) in diameter will generally exceed the strength of any slings used at the rigging point. Therefore, failure of a sound tree trunk is rather unlikely when snatching large diameter logs.

In contrast to the situation relating to normal arborist climbing activities, it is not possible to provide arborists with charts or tables of minimum diameters of branches required to sustain rigging operations. The considerable range of loads generated, branch angles, and lengths of lever arms, is far too wide to be incorporated in simple diagrams or rules. [...] Additionally, an understanding of how diameter, load angle and form of a branch union affect the strength of branches should certainly improve the assessment of temporary anchor points.

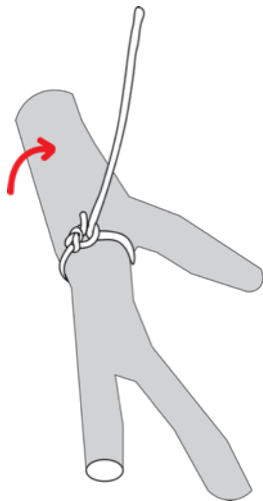
Fixed rope anchor points – attaching a rope



A fixed rope anchor point is where a rope is tied or secured to a tree part or other anchor.

The following pages show some different ways of attaching a rope for rigging, along with some advantages and disadvantages of each method.

Please note that this list is of examples only and is not intended to be exhaustive.



Running bowline

A very common way to attach a rope to a piece for rigging. Can slip – try to attach where a union or stub holds in place.

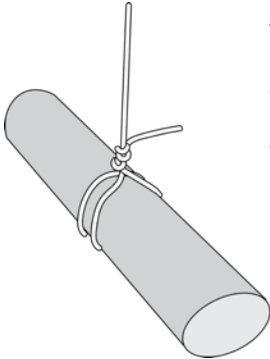
Advantages

- Can be used on any size piece.
- Easy to untie.
- Running bowline can be set 'at a distance' and pulled up tight.

Disadvantages

- Only cinches in one direction if branch rolls across longitudinal axis. (Non-cinching direction shown with red arrow).
- Doesn't 'bind' – can slip in dynamic rigging if temporarily loosened.
- Approximately 75% of rope strength retained, depending on rope and trunk diameter.

Round turn with 2 half-hitches

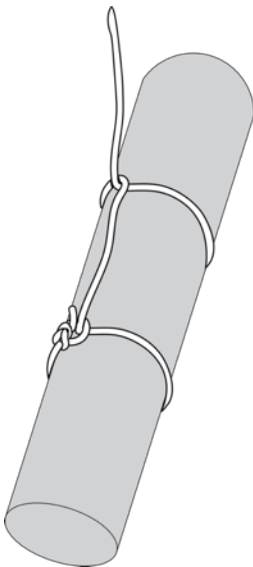


A good way to attach ropes to pieces for rigging. Retains more rope strength than any other attachment knot shown.

Advantages

- Can be used on any sized piece.
- Very easy to untie.
- The extra 'wrap' can help to prevent slipping.
- Can be untied under load if required.

Main attachment knot plus half-hitch

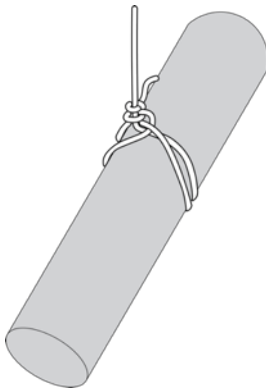


Advantages

- Can be used on any size piece.
- Easy to untie.
- Running bowline can be set 'at a distance'.
- Approximately 80% of rope strength retained.
- Can be used to alter balance.
- Helps to avoid slipping of main knot.

Disadvantages

- Moderately time consuming to install.
- Half-hitch will slip if loaded in the wrong direction – do not use when tying near mid-point!



Clove hitch with two half-hitches

or

Cow's hitch with better half

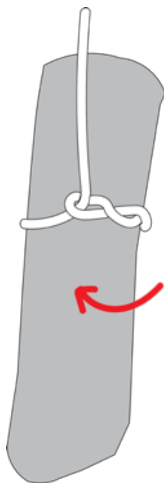
A clove hitch is a good and reliable way to attach rope to any size of timber. The cow's hitch (or cow hitch) can also be used but is more prone to slipping if the load rotates on its major axis.

Advantages

- Can be used on any size piece.
- Binds well – suitable for dynamic rigging. Will stay attached and 'tight' even when not under load.
- Approximately 80% of rope strength retained.

Disadvantages

- Moderately time consuming to install and untie.



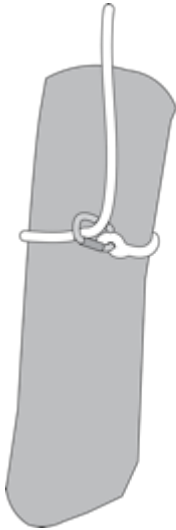
Timber hitch

The timber hitch should not be used in dynamic rigging applications or where the attached piece has the potential to roll across its major axis.

The timber hitch will only 'bite' or 'cinch' in one direction and will slip on the timber if it rolls in the wrong direction (red arrow shows non-binding direction).

Timber hitches can be used where the knot is protected or kept in a regular loading by the use of a pre-knot such as the half-hitch or marline hitch.

Karabiner



Wherever hardware is used in rigging scenarios, it is important to ensure that it is designed to be loaded in the configuration that it is being used.

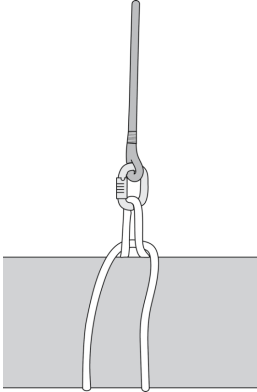
Most karabiners are not rated for load in any direction other than the major axis.

Cross-loaded karabiners (as in the image below) can break at extremely low loads, particularly where they are being ‘cantilevered’. See page 51, Rigging equipment configuration and use.

The use of karabiners to cinch rope onto timber, as shown in the image, should be limited to only those situations where failure of the rigging system will not result in damage or injury, for example:

- Attaching tag lines to guide branches into particular lowering zones.
- Lowering very small branches.
- Where the karabiner has a minor-axis rating and the unanticipated opening of the gate can be prevented.

The use of multiple wraps can reduce the load applied to karabiners but this does not address the issue of cross loading.



Karabiner and sling

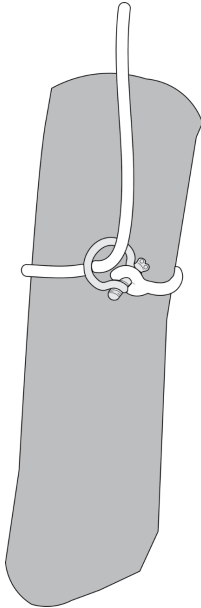
A quick way to attach and detach a spliced line from branches or timber. The use of multiple slings will allow the aerial worker to pre-set the next sling and quickly attach the line when it is returned.

Advantages

- Quick to install and easy to remove.
- Very fast way to deal with multiple small branches etc.
- Retains strength of rope (depending on splice and rope type).

Disadvantages

- Girth-hitched slings (as shown) can roll out if the branch rotates around its longitudinal axis.
- Karabiners can become side-loaded during dynamic rigging operations.
- Karabiners can impact trunk or other timber and be damaged.
- Rope wear is concentrated in splice.
- Slings must be large enough for circumference of piece.

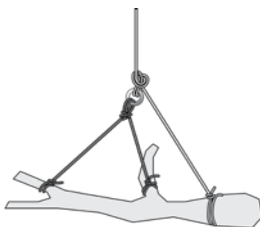


Shackle or similar connector

The use of shackles or other connectors which are designed to be cross-loaded in this manner is common on some tree work sites, in particular where cranes or other machines are in use.

Ensure that the pin (where present) is placed through the non-moving part of the rope – the splice in this case.

Siting the pin against rope which may move during rigging operations can loosen or undo the pin.



Other fixed-rope attachments

Many other solutions, attachments or combinations of attachments are of course possible.

The image on the left shows a spider-leg balancer constructed from the main rigging line, with one additional short rope joined mid-line.

Creative solutions to attachment problems are part of good rigging – but it is critical to ensure that the effects, resulting forces, behaviour of load and suitability of equipment are all understood before using new techniques.

Moving rope anchor points

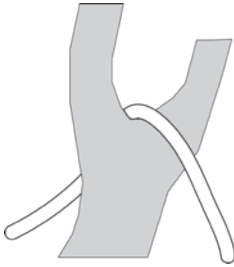


A moving rope anchor point is part of a rigging system where a loaded rope makes an angle and can be supported but will still be able to move freely.

Examples of moving rope anchor points include lowering blocks, branch unions, pulleys, rigging rings and similar hardware.

Moving rope anchor points inevitably exert some friction on the moving rope (depending on 'efficiency' of the pulley, block or other point), however, no additional friction is deliberately added (contrast with rope brake).

The following pages show many different moving rope anchor points and components for rigging, along with some advantages and disadvantages of each method. Please note that this list is of examples only and is not intended to be exhaustive.



Natural crotch

Natural crotch rigging describes the use of the tree's unions or other features as moving rope anchor points. It is the simplest and, in many cases, the most efficient way of conducting rigging.

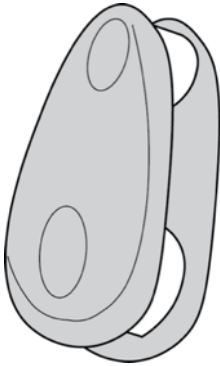
See page 136, Natural crotch rigging.

Advantages

- Very quick and easy to install and retrieve.
- Can be installed and retrieved from a distance (i.e. by throwing rope through fork or with throwline).
- No risk of dropping hardware.

Disadvantages

- Will damage many rope constructions/fibres.
- Will not work in tight/acute unions.
- Requires union to be in correct position for rigging system.
- High residual friction – will make lifting operations significantly more difficult; may concentrate fatigue in reduced section of rope.
- May reduce elastic elongation of cordage.
- Damages cambium – not suitable where tree part is to be retained.



Block, rigging block, impact block

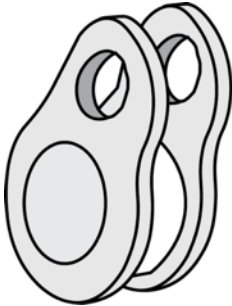
Blocks normally have two sheaves, arranged longitudinally. Blocks are usually attached with a textile connector, such as a dead-eye sling, loopie sling, whoopie sling or similar (see connectors below).

Advantages

- Durable and designed for dynamic shock loading.
- Low residual friction – useful in mechanical advantage systems or during lifting operations.

Disadvantages

- Can be heavy and comparatively expensive.
- Can be slow to install compared to other anchor points.



Pulleys

Pulleys usually have a single sheave, with an upper hole available for the use of a karabiner or other connector. A rigging pulley is designed to accept gradual loading, rather than dynamic impacts (contrast with rigging block).

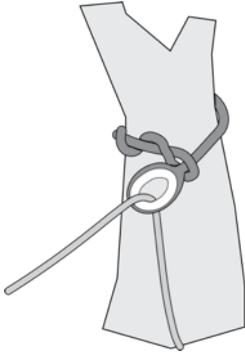
A pulley is normally attached to a structure using a karabiner or other hard connector, which is then attached to a dead-eye sling, tape sling, loopie sling or similar.

Advantages

- Can be cheap and light.
- Can be quick to install.
- Low residual friction – useful in mechanical advantage systems or during lifting operations.

Disadvantages

- Not suitable for dynamic loading or shock loads – it is easy for the karabiner or other connector to become cross-loaded or cantilevered, or for the pulley to be bent or loaded incorrectly.
- Addition of karabiner or other connector may introduce additional possible weakness.



Rigging rings

Rigging rings (also known as X-rigging rings, topping strops or snatching strops) are increasingly popular with tree workers.

The ring itself is spliced into a whoopie sling, dead-eye sling or similar (see connections below), which can be attached to a structure; the running rigging line is fed directly through the ring.

Advantages

- Cheap, lightweight, easy for the climber to carry and install.
- Some component of friction; will make it marginally easier for ground crew to manage rope for small pieces without additional rope brake.

Disadvantages

- Cannot be installed or removed mid-line.
- Care must be taken with bend radius – multiple rings may be required for larger diameter ropes.
- Some residual friction – may be less suitable for lifting operations.

Moving rope anchor point attachment components

Sling, tape sling, tube tape sling



Slings can be constructed of tube tape or rope.

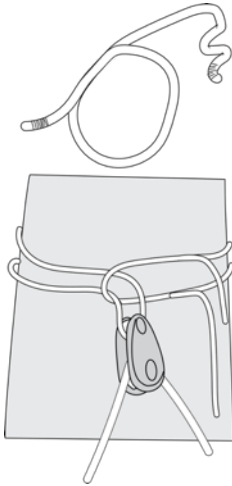
The sling is girth-hitched to the tree structure before installing rope through hardware.

Advantages

- Simple and cheap.
- Lightweight and quick to install.

Disadvantages

- No ability to adjust length makes it likely that hardware will hang below choke point – this can generate excessive force in negative rigging/snatching.



Loopie sling

Loopie slings are spliced rigging connectors that allow the size of the loop to be adjusted by 'milking' the cover over the buried section.

Adjust the loop size to fit the rigging device as tightly as possible – particularly for negative rigging.

Ensure that the bight on which the device is set is looped through the buried section of the loopie sling.

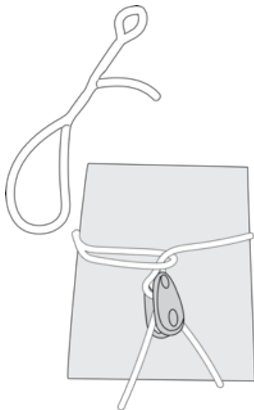
Advantages

- Large range of adjustability.
- Normally possible to fit hardware tightly to stem (use multiple wraps if necessary).
- Two arms of cordage at every part of connection – a strong configuration depending on cordage fibre.

Disadvantages

- Rope must be removed from device (or device from sling) whenever assembly is reset.
- Can be rolled around stem if pulled away from bite – if pulled to right in image shown.

Whoopie sling



Whoopie slings behave somewhat like loopie slings in that they have an adjustable loop, which can be changed in size by sliding the cover over the buried section.

Whoopie slings also have a spliced eye at one end. Hardware is fitted to this eye, which is then choked onto a tree or structure by passing the eye through the loop.

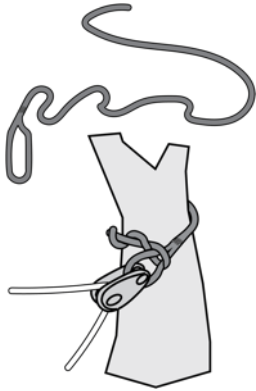
Advantages

- Large range of adjustability.
- Normally possible to fit hardware tightly to stem (use multiple wraps if necessary).

Disadvantages

- Rope must be removed from device (or device from sling) whenever assembly is reset.
- One arm of cordage at bury of splice – this is a weak point in whoopie slings. Avoid sitting the splice taper (end of the bury) across the loop when rigging.
- Can be rolled around stem if pulled in wrong direction – if pulled to left in image shown.

Weaker than a loopie sling unless set well.



Dead-eye sling

A dead-eye sling (or soft-eye sling) is a length of rope with an eye splice in one end.

The rigging device is attached to the eye, and the dead-eye sling is then attached to the structure (see **MIS301 Arborist Knots** and Fixed rope anchor point attachments, above).

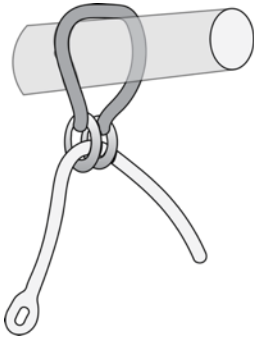
In the image shown, a dead-eye sling with a large eye has been used, so that the timber hitch can be installed around both arms of the eye.

Advantages

- Adjustable in size.
- Normally possible to fit hardware tightly to stem.
- Rope does not need to be removed from device to reposition sling. Excellent for running anchor usage.

Disadvantages

- Single arm of cordage at eye – use large eyes or cinch tightly. Weaker than loopie sling for given cordage strength.
- Depending on knots used, can be time consuming to install/reposition.
- Depending on knot type, can be prone to slipping when loaded in particular directions. In the image show, a timber hitch will slip when loaded to the left of the stem.



Other anchor points and attachment options

There are many other ways of attaching anchor points to trees and structures. The arboricultural community is extremely creative when devising ways to deal with technical trees ... or to save themselves a little work.

Solutions include:

- **Retrievable anchor points** (ring and ring [as shown below], 'rope guide' type rigging anchors, the use of anchor lines to set and retrieve anchor points.
- Rigging 'daisy chains' for quick adjustability.
- **Multiple point anchors** where load is shared – ensure that lateral force vectors on anchor points are understood (see **appendix b: working the angles**).

Rope brakes

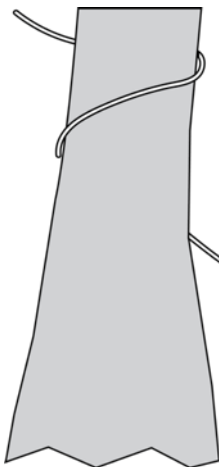


A rope brake is a part of a rigging system through which a loaded rope is able to move, where friction has been deliberately added to allow control over the movement of the load.

Examples of rope brakes include wraps around a tree, Portawraps, rigging bollards, drums, SafeBloc, rigging wrenches and other devices.

The following pages show many different rope brakes and components for rigging, along with some advantages and disadvantages of each method. Please note that this list is not intended to be exhaustive.

Trunk wraps



Friction can be added by wrapping the rigging line around the trunk of the tree or around adjacent trees.

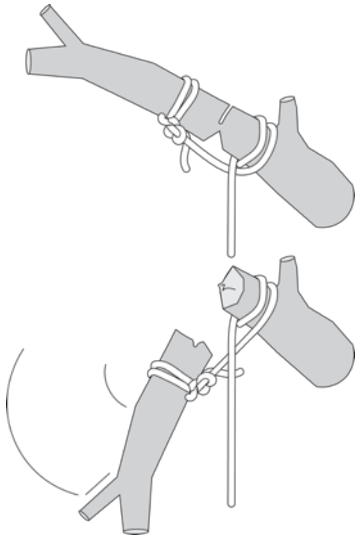
Advantages

- Large bend radius means high proportion of rope strength retained; no equipment required.
- Possible to add lots of friction for very large rigging forces if required.
- Can be used in conjunction with other devices to reduce load on lowering device.

Disadvantages

- Damages rope and cambium – not suitable where tree part is to be retained.
- Slip of rope on trunk makes it difficult to fully pre-tension; can be very slow to wrap and unwrap.

Wraps in tree



The use of trunk or branch wraps is an excellent method of applying friction in a rigging system. There are many different techniques and applications. Please see page 138, Applying friction at the point of cut and **Appendix B: Working the angles**, for more details.

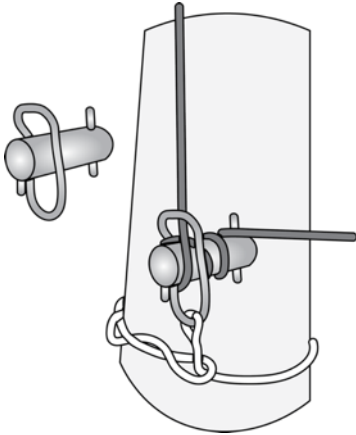
Advantages

- Very quick and easy to install and retrieve if applied at point of cut – may be possible for climber to control.
- No risk of dropping hardware.
- Taking friction in tree may reduce magnitude of force (see **Appendix B: Working the angles**).

Disadvantages

- Will not work in tight/acute unions.
- Requires union to be in correct position for rigging system. If improperly installed rope can slip off the remaining stub and piece will fall.
- Leaves a stub which may need to be cut back.
- Can be harder to judge amount of wraps correctly as branch diameter/variations in bark texture will all have an effect. Harder to get pieces to run smoothly.
- High residual friction – will make lifting operations impossible if branch becomes stuck.
- Damages rope and cambium – not suitable where tree part is to be retained.

PortaWrap or similar floating friction brake



The PortaWrap is a friction device originally designed in the early 1990s. It is available in multiple sizes for different load ratings and rope diameters. Several other manufacturers have since produced similar devices.

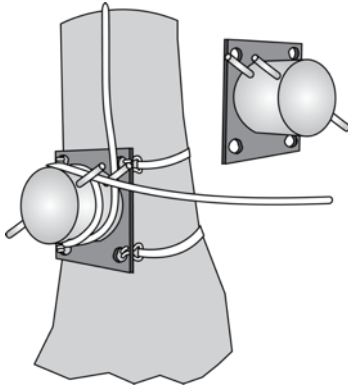
Advantages

- Cheap, easy to install, lightweight, suitable for use in dynamic applications.
- Does not damage rope or cambium if used correctly.
- Can be used at base of tree or as an aerial friction device.
- Can be used to capture slack as part of a mechanical advantage lifting system.
- Rope can be 'locked off' on retention pins if necessary.

Disadvantages

- Low WLLs may make the PortaWrap unsuitable for many larger tree jobs.
- WLL varies depending on attachment cordage and device size. Large Portawraps have a WLL of approximately 8.8 kN (2000 lbs) and a maximum rope diameter of 20mm (3/4").
- Tight bend radius (when compared to a bollard or trunk wraps) reduces rope strength and puts twists in rope during rigging operation.

Bollard, drum or similar



A wide variety of drums and bollards are commercially available for use in tree rigging. **Important factors for consideration when selecting a bollard include:**

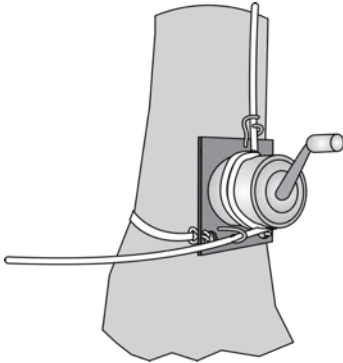
- Does it need to be 'cut into' the tree?
- What cordage diameters will it function with?
- Does it have lugs or retention pins where the rope can be locked-off if required?
- What is the WLL and MBS?
- Does it have any capacity to apply tension to rope, or is there a facility for mechanical advantage systems to be added?

Advantages

- Suitable for use in dynamic applications.
- Does not damage rope if used correctly – may also protect tree (depending on model).
- Can be used to capture slack as part of a mechanical advantage lifting system.
- Rope can be 'locked off' on retention pins if necessary.

Disadvantages

- Heavy, can be slow to install, comparatively expensive.
- Normally only accepts loading in a particular direction or plane – not suitable for in-tree use and care must be taken with setup to avoid accidents.



Capstan or other mechanical advantage device

Several friction brakes are available that incorporate the ability to add mechanical advantage.

Capstans can be modular, or replaced with an optional bollard, depending on model.

Most capstans are not designed to accept dynamic loading – ensure that rigging setups do not apply shock load to equipment which is not designed for it.

Important factors for consideration when selecting a bollard include:

- Does it need to be 'cut into' the tree?
- Can it be used for dynamic rigging applications?
- If not, is it easy to re-configure for dynamic loading (replace capstan with bollard, etc.)?
- What rope diameters will it accept?
- What is the WLL/MBS? What mechanical advantage can it apply?

Advantages

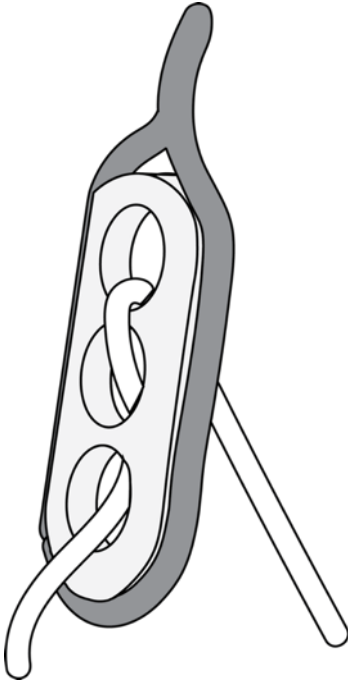
- Does not damage rope if used correctly – may also protect tree (depending on model).
- Can be used for lifting operations, to pre-tension lines, and to raise stuck branches where previous rigging has become hung up.
Quickest method of applying tension; great if lots of lifting required.
- Rope can be 'locked off' on retention pins if available.

Disadvantages

- Not suitable for use in dynamic applications (depending on model).
- Heavy, can be slow to install, expensive.
- Normally only accepts loading in a particular direction or plane – not suitable for in-tree use and care must be taken with setup to avoid accidents.

SafeBloc or similar aerial friction brake

The SafeBloc is a three-hole rigging thimble. The SafeBloc provides a set amount of friction depending on cordage type and diameter. Several similar 'multiple hole thimble' products are available.



Advantages

- Comparatively light and easy to install (compared to other artificial friction brakes).
- May provide enough friction to eliminate the need for other rope brakes and may reduce load at anchor point (for in-tree applications).

Disadvantages

- Rope must be pulled back against friction.
- Cannot be installed midline.
- Amount of friction provided is not adjustable – may be insufficient for one piece, then too much for the next.
- Larger and heavier than a comparably rated rigging block.
- May increase lateral components of force during negative rigging.

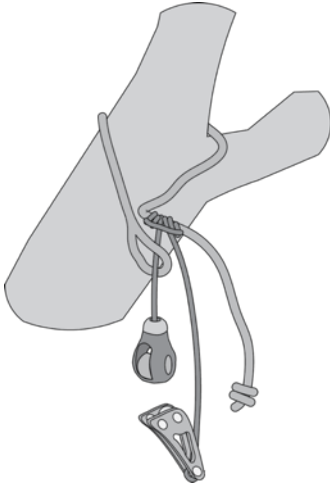
Other rope brake options

There are many other devices available to provide friction:

A **rigging wrench** (removable 'wrench guide' shown to left) to provide friction when piece is lowered and to remove friction during lifting or rope return.

The **aerial friction brake** – a bollard within the housing of a rigging block so that wraps can be taken aerially.

Figure-8s, Munter hitches or similar devices can allow friction to be added to a rigging scenario, however these tend to result in severe hockling of rigging ropes used.



Rigging equipment configuration and proper use

Configuration of rigging equipment describes the manner in which components are assembled within a rigging system and the ways they will be loaded in this assembly.

Correct selection and configuration of components within a rigging system is critical for rigging system design. The range of rigging equipment available for use in tree work is too large for a full description of correct and incorrect use to be presented here. Operators should consult manufacturer's instructions, user manuals, and seek training from reliable sources.

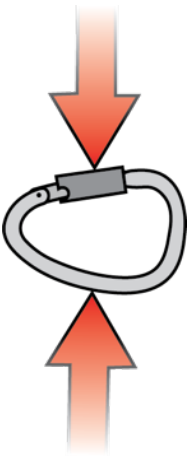
Online videos, chat rooms or similar are an extremely poor source of guidance for tree work – equipment is regularly misused in these forums and techniques are often inappropriate.

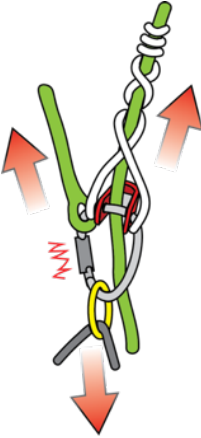
The table below contains examples of misconfigured or inappropriate use of karabiners – although this list of examples is not exhaustive, it is intended to be used as an example of how even an apparently simple component can be misused.



Karabiner loading	Image	Description
Karabiner used with gate sleeve unlocked		A locking karabiner used with the gate sleeve (screwgate, triple-locking, double-auto-locking or similar) unlocked. This can allow the gate to open (see below) as well as allowing suspended loads to be disconnected from the rigging system and fall.
Karabiner used with gate in the open position		Karabiners with the gate open are very weak. Assume 30% or less of the major axis strength, depending on model.

Karabiner loading	Image	Description
Karabiner loaded across a minor axis		A karabiner cross-loaded or loaded across the minor axis, is very weak. Assume 35% or less of the major axis strength, depending on model. Some karabiners have a printed minor axis rating.⁴ The decision to use these in any minor axis configuration should still be avoided – the risk of accidental loading across the gate or cantilevering is high.
Karabiner loaded multi-directionally		The strength loss in this configuration will depend on the angle between the separated loads, and how far that angle deviates from the longitudinal axis.
Karabiner loaded over an edge		Strength loss in this configuration will depend on angle of edge, angle of loading and attachment to karabiner. Karabiners will retain no more than 30% of their printed longitudinal rating if used in this configuration, and the actual strength may be significantly less.

Karabiner loading	Image	Description
Pressure on gate or gate sleeve		Gate sleeves may be extremely weak. According to the usage guide for Petzl karabiners: • The European standards require a sleeve strength of 1 kN under external pressure (a value easily reached in the field). • Certain standards require much higher strengths, for example 16 kN for the ANSI Z359.12 standard. Avoid using karabiners in dynamic rigging applications where loads may crush them against tree parts or other hardware.
Cantilevered loading		Cantilevered loading occurs where the position of the karabiner is fixed and torque is applied to one of the arms. This is surprisingly easy to achieve with misconfigured rigging equipment and will result in a significant and hard-to-predict reduction in the strength of the karabiner. It may also damage the rigging hardware (pulley etc.) through which cantilevered force is being applied.

Karabiner loading	Image	Description
Overloaded karabiners (multi-directional loading; loading across single arm)		Although the image shown is an example of overloading in a climbing rather than a rigging application, the same principles apply. Too many components have been attached to this karabiner, preventing proper alignment and proper loading. The separation of the loads at the top is applying multidirectional loading to the karabiner. In addition, if the two sides of the rope receive uneven loading, the load will not be evenly shared between the two main arms of the karabiner. In particular, heavy loading on the spliced arm of the rope (during climbing ascent for example) will load the karabiner almost exclusively along the gated arm. Karabiner strength in this configuration may be 30% or less of the printed main axis strength.
Images adapted by author from www.petzl.com, examples of unsafe karabiner loading⁴.		

Example of misconfigured rigging equipment



Tape sling

- Tape sling too small for application.
- Tape sling at risk of being cut by sharp edge of pulley.
- Tape sling receiving cantilevered load from pulley.
- Tape sling experiencing rope-on-rope contact from running loaded rigging line.
- Tape sling may be damaged by excessive heat build-up in pulley (see below).

Karabiner

- Karabiner cross loaded.
- Karabiner receiving cantilevered, uneven loading from pulley.
- Karabiner gate rubbing on trunk (risk of opening).
- Karabiner gate sleeve crushed against trunk.

Pulley

- Pulley receiving uneven cantilevered load from karabiner.
- Pulley cantilevered across lower arm of tape sling.
- Pulley loaded across side plate rather than sheave.
- Rope rubbing across edge of side plate.
- Heat build-up from rope running incorrectly.

Rope

- Rope running over sharp edge of pulley side plate – can be cut or fatigued.
- Rope bent sharply over side plate edge – bend radius too tight.
- Rope can be damaged by heat build-up in pulley.
- Rope-on-rope contact with tape sling.

Designing a rigging system

Before rigging components can be assembled, the rigging system as a whole must be designed.

- Identify which parts of the tree or trees will require rigging.
- Determine suitable lowering zones for rigged parts.
- Assess the tree as a whole and consider each part that will need to be rigged. Choosing a rigging system that will not need to be altered frequently is usually preferable. Where alterations are required, try to find systems where making the alterations will be as energy efficient as possible.
- Some operations will require a unique rigging system to be set up to make just a single challenging cut, which must then be completely reset for the next one. Do not try to shortcut this process by attempting rigging operations where the outcome is uncertain!
- Identify the anchor points which will be used in the rigging system/s and consider their suitability for the intended use.
- Ensure that the equipment that is available is appropriate for use in the configurations that are intended.
- Ensure that ground crew are familiar with the techniques that will be required of them.
- Ensure that piece size is appropriate for both lowering zone area and crew processing capacity.
- Ensure that rigging techniques are within the level of experience and competence of each crew member on site.
- Be flexible with planning and don't be afraid to change plans as the situation may change, due to factors such as crew size or weather. The situation may look very different from up in the tree to how it looked from the ground!

Discussing rigging systems

Taking the time to discuss tree-rigging operations is not time wasted. A careful discussion of proposed rigging system/s will allow:

- All crew members on site to understand intended rigging operations and identify their own work roles.
- Input from all crew members as to possible alterations or improvements of intended operations.
- All crew members to become more familiar with equipment, terminology and rigging systems, improving work skills and making future rigging operations run more smoothly.

For a list of rigging system examples, including some specific considerations relevant to each system, please see **Appendix A: Rigging system diagrams**.

Rigging system design considerations

Tree work is not physics. Most arborists go through their whole careers without working out peak load for dynamic rigging operations – by taking sensible pieces, building experience, operating with sufficient safety factors and not pushing gear or tree structure ‘to the limit’, good rigging systems can be designed using experience and common sense. Good rigging systems:

- Are **safe** – shock loading is minimised, cuts are made from a protected position, and the tree structure and rigging components will not be damaged if the piece binds up unexpectedly or does ‘the worst thing possible’.
- Are **efficient** – quick to install, easy to detach and allow for a short recycle time between each operation.
- Work to the **processing capacity** of the ground crew. Rigging half the tree in one cut may be deeply inefficient if a small crew on the ground are unable to quickly bring it down and clean it up.
- Are **energy efficient** for both climber/ewp operator and ground crew. Good rigging system design should incorporate the return of the line to the aerial worker without excessive ‘flicking’ or throwing, should allow pieces to be lowered into the clearest space available and should look to move pieces toward the chipper where possible. It is often worth investing 15 minutes at the start of the day in system installation if it can save hours of stuck branches or dragging debris.
- Are **simple**. While it may be tempting to build a complex system with multiple anchor ropes and floating components, many tree-rigging operations are best conducted by using a simple rigging system design and lowering smaller pieces!

Nevertheless, it is important to have an understanding of some of the forces and loads that equipment and structures will be experiencing, in order to select appropriate equipment and maintain suitable safety margins. The first step in working out the forces involved is always to work out the weight of the intended load.

Estimating weight of sections

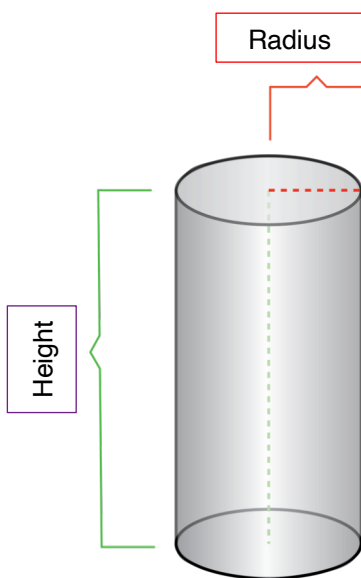
There are several mathematical methods available to help arborists estimate the weight of sections to be rigged, as well as a range of apps and calculating tools. Several studies applying these techniques have found a significant variation between estimated and actual weight of pieces – **an additional safety factor of at least 25% should be applied in calculations as standard when estimated weights approach WLL of any component in a rigging system³.**

Equation for weight of a given section of tree:

$$\text{Weight} = \text{Volume} \times \text{Density}$$

To estimate the weight of a section, **begin by calculating its volume.**

Estimating volume of trunk wood



For a cylindrical piece such as the straight log shown on the left, the equation for **volume** is:

Equation for volume of a cylinder

$$\text{Volume} = \pi r^2 h$$

π is the Pi symbol, a constant of 3.142
 r is the radius of the section, measured in metres
 h is the height of the section, measured in metres

One option to include a suitable safety factor is to **use a value of π of 4.0** instead of 3.142. This will make calculations easier and will provide a safety factor of approximately 25%.

This simplification is suggested for use when rough-estimating weights for general use, or when concern is the SWL of system components. For lifting operations or where accurate weights are required, the correct use of π is recommended.

Rules of thumb for estimating volume of irregular logwood sections

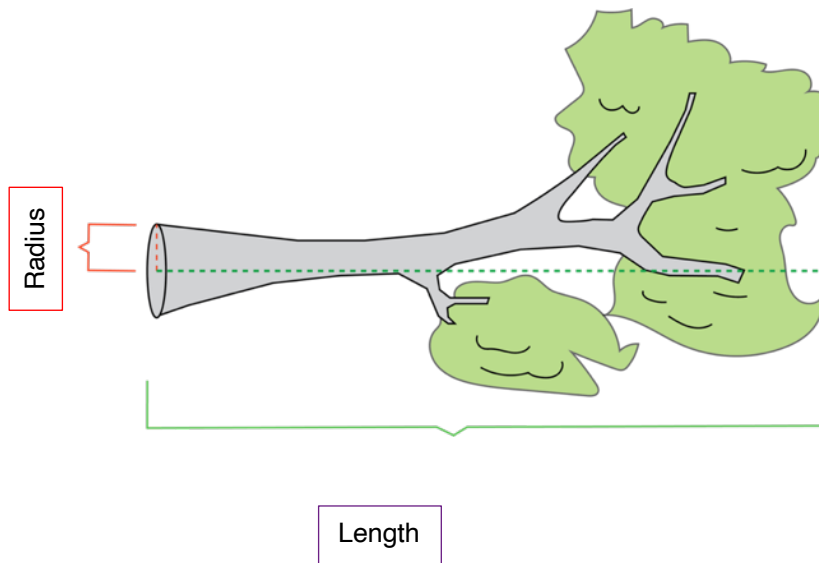
Option 1: choose a **representative diameter** which you feel accurately reflects the average diameter of the piece, then divide by 2 to get the radius

Option 2: assess the position of the centre of gravity and measure the diameter at this point, then divide by 2 to get the radius

Factors such as cavities, decay, unions, swellings and other irregularities may make accurate estimation difficult. Err on the side of caution!

Estimating volume of branches

Calculating the **volume of branches** is more challenging. The same formula is used to calculate volume but the taper of branches coupled with the end-weight, complex branching structures and foliage matter means that a correction must be applied.



The adjusted equation includes a **form factor**, which is written as ***f***. This is an approximate constant that is incorporated in order to simulate the likely taper, end weight, foliage distribution etc.

Form factors between 0.5 and 0.84 have been recorded in tests in the UK; a suggested standard of 0.8 is proposed in the HSE UK *Evaluation of Current Rigging and Dismantling Practices used in Arboriculture*³.

Equation for volume of a branch or stem

$$Volume = \pi r^2 L f$$

π is the Pi symbol, a constant of 3.142

r is the **radius of the branch at the union**, measured in metres

L is the **length of the branch**, measured in metres

f is the **form factor** (suggested 0.8).

If a form factor of 0.8 is to be used, the equation can be simplified by multiplying π by 0.8 to give a single constant of 2.5. If this is used, the equation will read:

$$2.5 r^2 L$$

Note that no safety margin beyond the high form factor has been incorporated in this figure. Altering the form factor will alter the safety margin that is being used.

Calculating the weight of tree parts

Multiplying the volume by the **density** (weight per m³) of the piece will give you its weight.

$$\text{Weight} = \text{Volume} \times \text{Density}$$

Tree densities

As a rough guide, most Eucalyptus species can be assumed to be around 1000 kg/m³ when green and from 800 kg/m³ to 900 kg/m³ when dead and dried.

The table on the following pages provides the green densities for a range of trees which are commonly dismantled in New Zealand and Australia. The data has been compiled from multiple sources, and reviewed by experienced arborists in both countries to identify any anomalies. Where different sources provided varying density values, a range is presented.

In some cases, green weight data was not available, and the density provided has been calculated by adjusting the known dry density by an assumed green moisture content.

A wide range of densities will occur, even within a single tree. If the cut section includes a higher proportion of sapwood, or if there is significant decay the weight may be lower. At different times of year the density will vary, as the moisture content changes. Trees grown in different environments, or trees of a different age class, will have different timber properties.

The densities provided below are intended to be used as a starting point, and to ensure that rigging operations are conducted within the Safe Working Loads of all of the equipment in the system.

Tree species density table

Species	Common name	Green density (kg/m ³)
<i>Abies alba</i>	Silver Fir	850 ^c
<i>Abies procera</i>	Noble Fir	690 ^c
<i>Acacia dealbata</i>	Silver Wattle	800 ^a
<i>Acacia melanoxylon</i>	Blackwood	870 ^a
<i>Acer platanoides</i>	Norway Maple	980 ^c
<i>Acer pseudoplatanus</i>	Sycamore	840 ^c
<i>Aesculus hippocastanum</i>	Horse Chestnut	880 ^c
<i>Agathis australis</i>	Kauri	800 ^d
<i>Agathis robusta</i>	Queensland Kauri	720 ^a
<i>Allocasuarina torulosa</i>	Rose She-Oak	1160 ^a
<i>Angophora costata</i>	Smooth-barked Apple	1240 ^a
<i>Beilschmiedia tawa</i>	Tawa	950 ^d
<i>Betula pendula</i>	European Birch	840 ^d
<i>Castanea sativa</i>	Sweet Chestnut	1,000 ^c
<i>Casuarina cunninghamiana</i>	River She-Oak	970 ^a
<i>Chamaecyparis lawsoniana</i>	Lawson's Cypress	700 ^c
<i>Corymbia citriodora</i>	Lemon-scented Gum	1150 ^a
<i>Corymbia maculata</i>	Spotted Gum	1150 ^a
<i>Cupressus</i> sp.	Cypress	550–710 ^b
<i>Dacrycarpus dacrydioides</i>	Kahikatea	600 ^d
<i>Dacrydium cupressinum</i>	Rimu	800 ^d
<i>Dysoxylum spectabile</i>	Kohekohe	800 ^d
<i>Elaeocarpus dentatus</i>	Hīnau	950 ^d
<i>Eucalyptus camaldulensis</i>	River Red Gum	1130 ^a
<i>Eucalyptus cladocalyx</i>	Sugar Gum	1100 ^b
<i>Eucalyptus cypellocarpa</i>	Mountain Grey Gum	1100 ^a
<i>Eucalyptus diversicolor</i>	Karri	1200 ^a
<i>Eucalyptus globulus</i>	Blue Gum	1100 ^a

Species	Common name	Green density (kg/m ³)
<i>Eucalyptus microcarpa</i>	Grey Box	1170 ^a
<i>Eucalyptus obliqua</i>	Messmate Stringybark	1080 ^a
<i>Eucalyptus paniculata</i>	Ironbark	1210 ^c
<i>Eucalyptus regnans</i>	Mountain Ash	1030 ^c
<i>Fagus sylvatica</i>	European Beech	1030 ^c
<i>Fraxinus excelsior</i>	European Ash	800 ^c
<i>Fuscospora fusca</i> (syn. <i>Nothofagus fusca</i>)	Red Beech or Tawhai Raunui	1050 ^d
<i>Fuscospora truncata</i> (syn. <i>Nothofagus truncata</i>)	Hard Beech	1200 ^d
<i>Gleditsia triacanthos</i>	Honeylocust	1050 ^c
<i>Juglans nigra</i>	Black Walnut	910 ^c
<i>Knightia excelsa</i>	Rewarewa	1000 ^d
<i>Kunzea ericoides</i>	Kanuka	1200 ^d
<i>Larix decidua</i>	European Larch	810 ^c
<i>Libocedrus bidwillii</i>	Kaikawaka or Pahautea or New Zealand Cedar	650 ^d
<i>Liquidambar styraciflua</i>	Sweet Gum or Liquidambar	930 ^c
<i>Liriodendron tulipifera</i>	Tulip Tree	750 ^c
<i>Lophostemon confertus</i>	Brush Box	1160 ^a
<i>Magnolia grandiflora</i>	Evergreen Magnolia	950 ^c
<i>Metrosideros excelsa</i>	Pōhutukawa	1300 ^d
<i>Metrosideros robusta</i>	Northern Rātā	1200 ^d
<i>Metrosideros umbellata</i>	Southern Rātā	1400 ^d
<i>Nestegis cunninghamii</i>	Black Maire	1350 ^d
<i>Phyllocladus trichomanoides</i>	Celery Pine or Tanekaha	900 ^d
<i>Picea abies</i>	Norway Spruce	800 ^c
<i>Pinus ponderosa</i>	Ponderosa Pine	790 ^c
<i>Pinus radiata</i>	Radiata Pine or Monterey Pine	760 ^{a, c}
<i>Pinus sylvestris</i>	Scots Pine	820 ^c

Species	Common name	Green density (kg/m ³)
<i>Platanus x acerifolia</i>	London Plane	1000 ^c
<i>Platanus x hispanica</i>	European Plane	840 ^c
<i>Podocarpus totara</i>	Totara	650 - 750 ^d
<i>Populus nigra</i>	Black Poplar	670 ^c
<i>Prumnopitys taxifolia</i>	Matai	950 ^d
<i>Pseudotsuga menziesii</i>	Douglas Fir	670 ^c
<i>Pyrus communis</i>	Pear	880 ^c
<i>Quercus cerris</i>	Turkey Oak	1040 ^c
<i>Quercus robur</i>	English Oak	1010 ^c
<i>Robinia pseudoacacia</i>	Black Locust	900 ^c
<i>Salix alba</i>	White Willow	760 ^c
<i>Sequoia sempervirens</i>	Redwood	850 ^c
<i>Sorbus torminalis</i>	Wild Service Tree	900 ^c
<i>Thuja plicata</i>	Western Red Cedar	570 ^c
<i>Tilia vulgaris</i>	European Lime	670 ^c
<i>Ulmus procera</i>	English Elm	1030 ^c
Sources:		
a.	Bootle, K. R. (Keith R.) 2005, <i>Wood in Australia: types, properties and uses</i> , 2nd ed., McGraw-Hill, Sydney	
b.	Wallis, N.K. (1956), <i>Australian Timber Handbook</i> , 1 st ed, Timber Development Association of Australia, Sydney.	
c.	Health and Safety Executive (2008), <i>Evaluation of Current Rigging and Dismantling Practices used in Arboriculture</i> , UK/	
d.	Manaaki Whenua - Landcare Research: <i>native species wood density dataset</i>. [https://datastore.landcareresearch.co.nz/dataset/f1d19470-c956-4a41-bee5-fe9a3176f0af/resource/8603028c-24be-48a0-aadc-53cf428228a1/download/specieswooddensitydata.txt] retrieved 18.05.2020. Based on density measurements of dried timber, adjusted by an assumed green moisture content and reviewed	

Introduction to forces in rigging

Tree workers should aim to have at least a basic understanding of the ways in which forces are applied in a rigging system.

While experience is an excellent guide, it relies heavily on 'this worked last time, so I will do it again'. Operating in this manner does not give any warning that operations are exceeding the WLL or approaching failure – the first sign will be when something breaks!

This section covers some concepts for forces in rigging systems and techniques for estimating loads. Throughout this section loads will be discussed in kilograms (a unit of mass not weight but used as weight in this situation) and the following assumptions are made:

- Pulleys and blocks are assumed to be perfectly efficient.
- Rope is assumed to have no elongation.

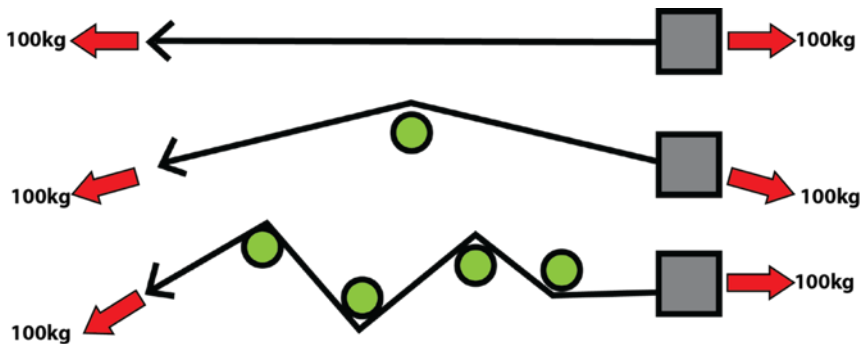
A more in-depth discussion about forces in rigging can be found in **Appendix B: Working the angles.**

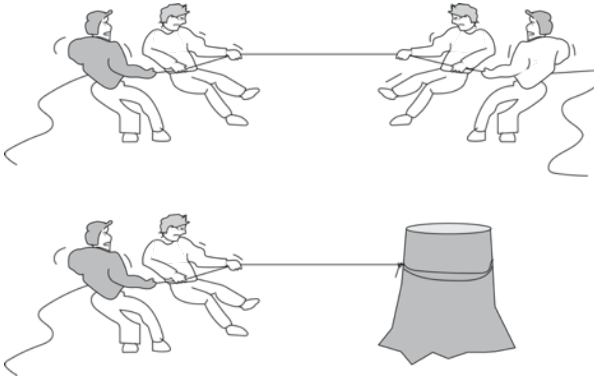
1: Forces in ropes

When a rope is loaded or pulled in one direction with a particular amount of weight or force, **it must be loaded in the other direction with the same amount of weight or force or it will move.** For the moment, assume that this will be true no matter whether the rope passes over a pulley or not.

For rigging, this means that if 100 kg piece of wood mute b suspended, the other end of the rigging line must be pulled with 100 kg of weight or the piece of wood is going to start moving down.

This is an arboricultural translation of Newton's third law: **for every action there must be an equal and opposite reaction.**



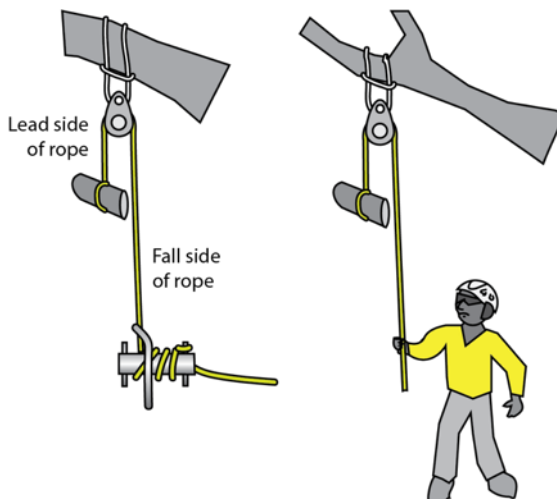


2: Tying off ropes

If rope is secured at one end and then the other end is pulled, the anchor point will provide the same equal and opposite reaction as another crew pulling on the rope.

In other words, in the top image the right-hand crew are pulling the rope to the right with 100 kg – and the tree stump is doing exactly the same.

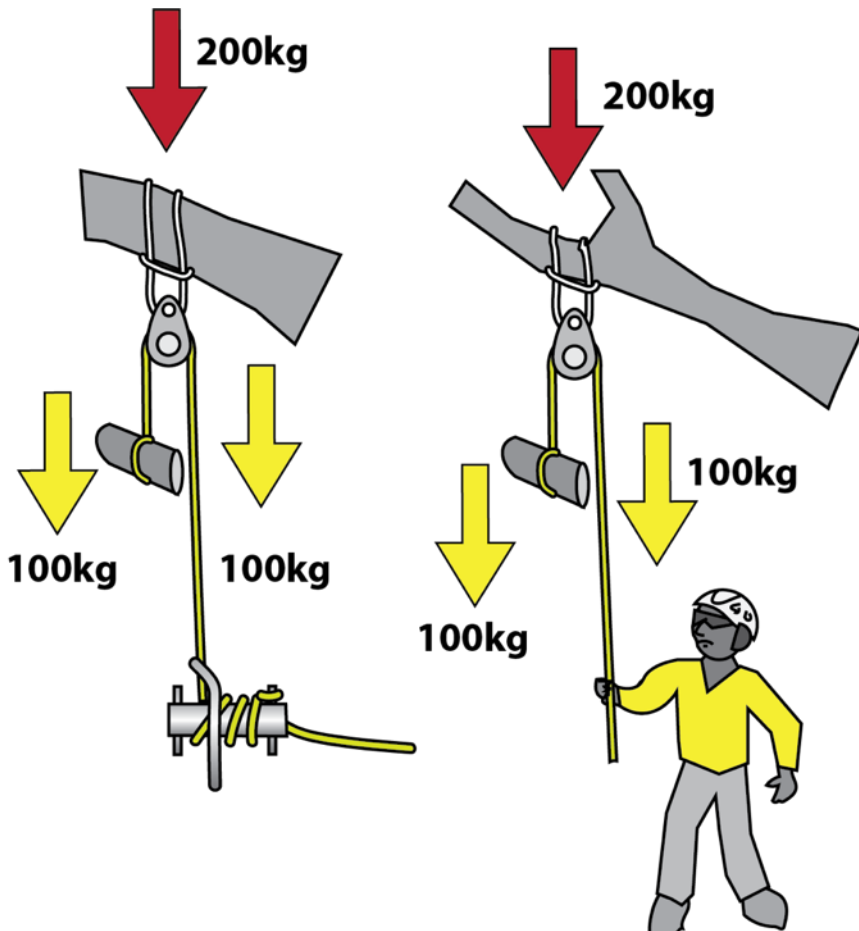
In the lower images, both the Portawrap and the tree worker are being lifted up by the log with 100 kg of weight ... and are therefore pulling down on the rope with 100 kg of weight to avoid being pulled into the tree.



3: Simple mechanical advantage

We have seen that, as in the image below, if a load of 100 kg is applied to the **lead side** of a rope, a similar load of 100 kg must be applied at the **fall side** or the rope will move and the piece will be lowered.

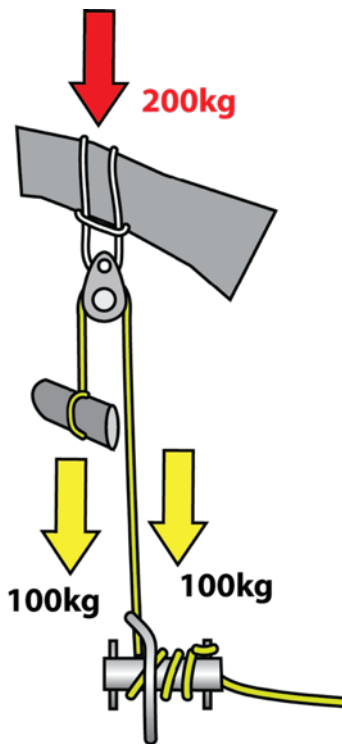
Consider how those loads will affect the anchor point – the rigging block shown in the image below. We have seen that each arm of the rope is being pulled down with 100 kg: in this simple setup, **where both sides of the rope are parallel**, the anchor point will be pulled down with 200 kg of weight.



Different loads on components in rigging system

Because of the increased load on the anchor point, it is **critical that rigging system components are selected for the load they will receive in the configured system.**

In most systems where a rigging block or pulley is used and friction is applied at the base of the tree, the anchor point components (including block, connectors and structure it is attached to) will receive double the load that is in the rope or that is applied to the rope brake. In this type of rigging system, the rope should be the weakest link.



Rope = 100 kg

Consequence of rope failure: system is separated – load falls – loading of components ceases. Rope can still be lethal – particularly with more elastic ropes!

Rope brake = 100 kg

Consequence of rope brake failure: load falls – rope brake components may travel into the tree and impact worker.

Anchor point (including structure) = 200kg

Consequence of anchor point failure: components fall – possibly including tree parts – rope system still intact; if loop of rope falls across other tree parts further shock loading will result – loop of rope will fall over everything below anchor point.

On the previous page, the images showed an example of simple mechanical advantage. We saw that when one side of a rope is loaded and the other is locked off, this is the result:

Ropes running parallel = double the force on the anchor point

This is an important rule for tree workers to remember. In practical applications however, an enormous variety of rigging systems are possible and ropes make many different angles at anchor points.

The rule above needs to be expressed in ways that will allow us more flexibility in how we understand forces during tree work. To do so, we need to introduce the concept of a **force vector** – this is a way of describing both the **magnitude** of a force and its **direction**.

4: The angle rule

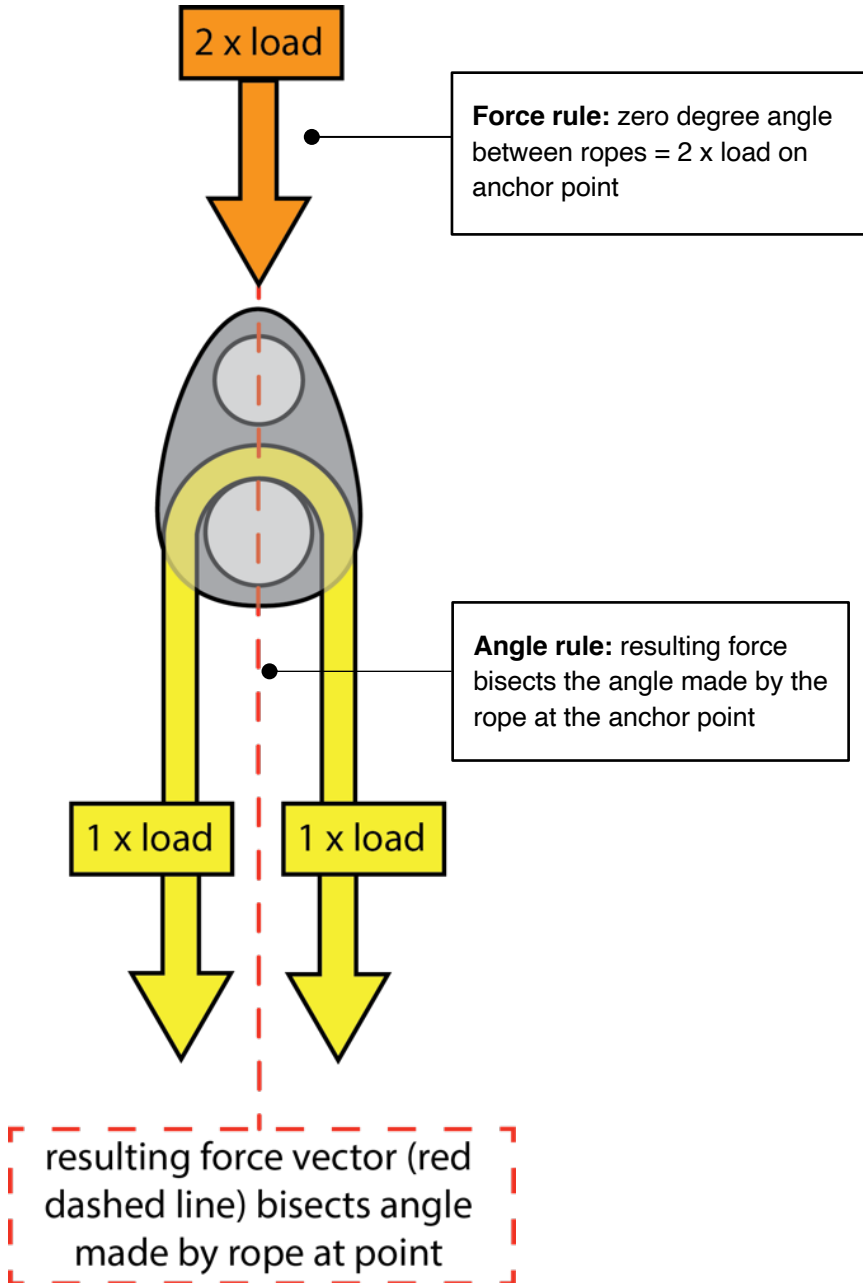
The direction of the net force applied by a rope passing over a point bisects the angle made by the rope at the point.

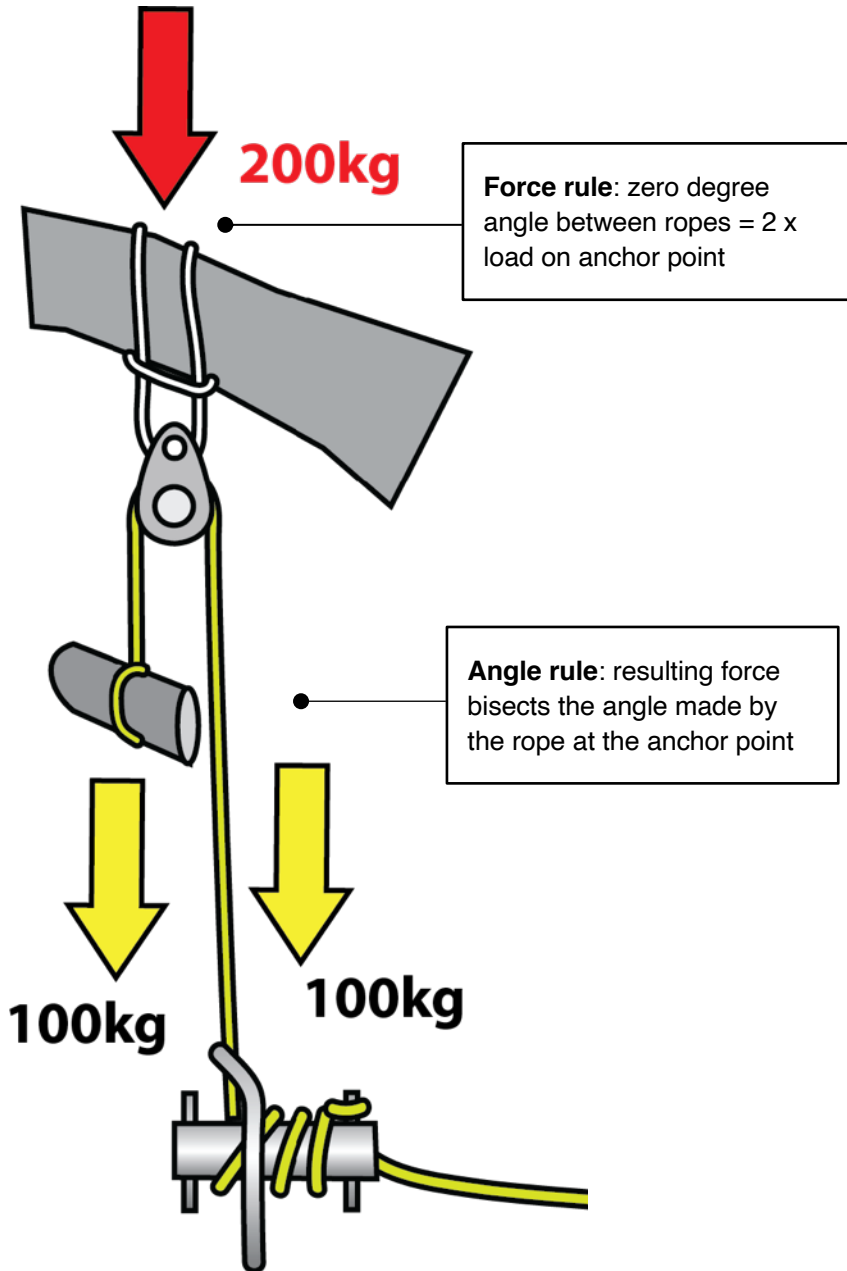
Note that this rule ignores the effects of friction at the point – this can alter both the magnitude and direction of the resultant force vector. The rule is still useful though, as it can give a useful ‘rule of thumb’ for building rigging systems, particularly where those systems will be used for dynamic rigging or for both lifting and lowering.

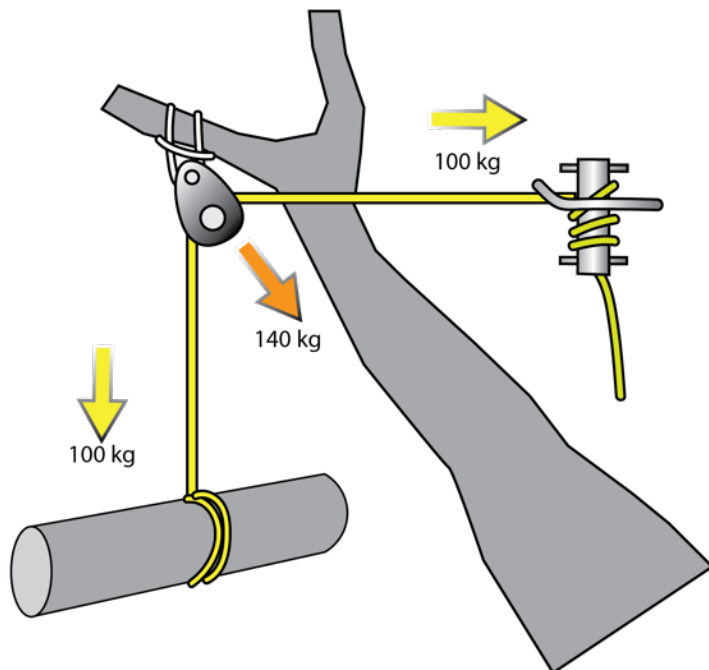
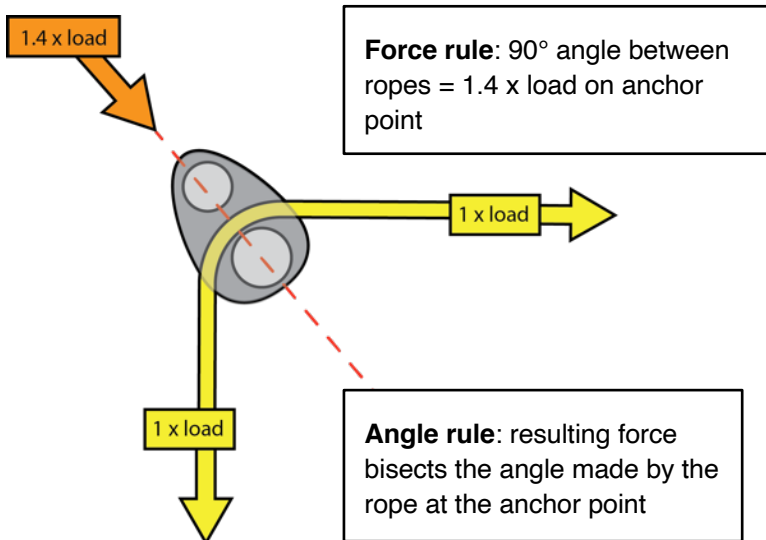
5: The force rule

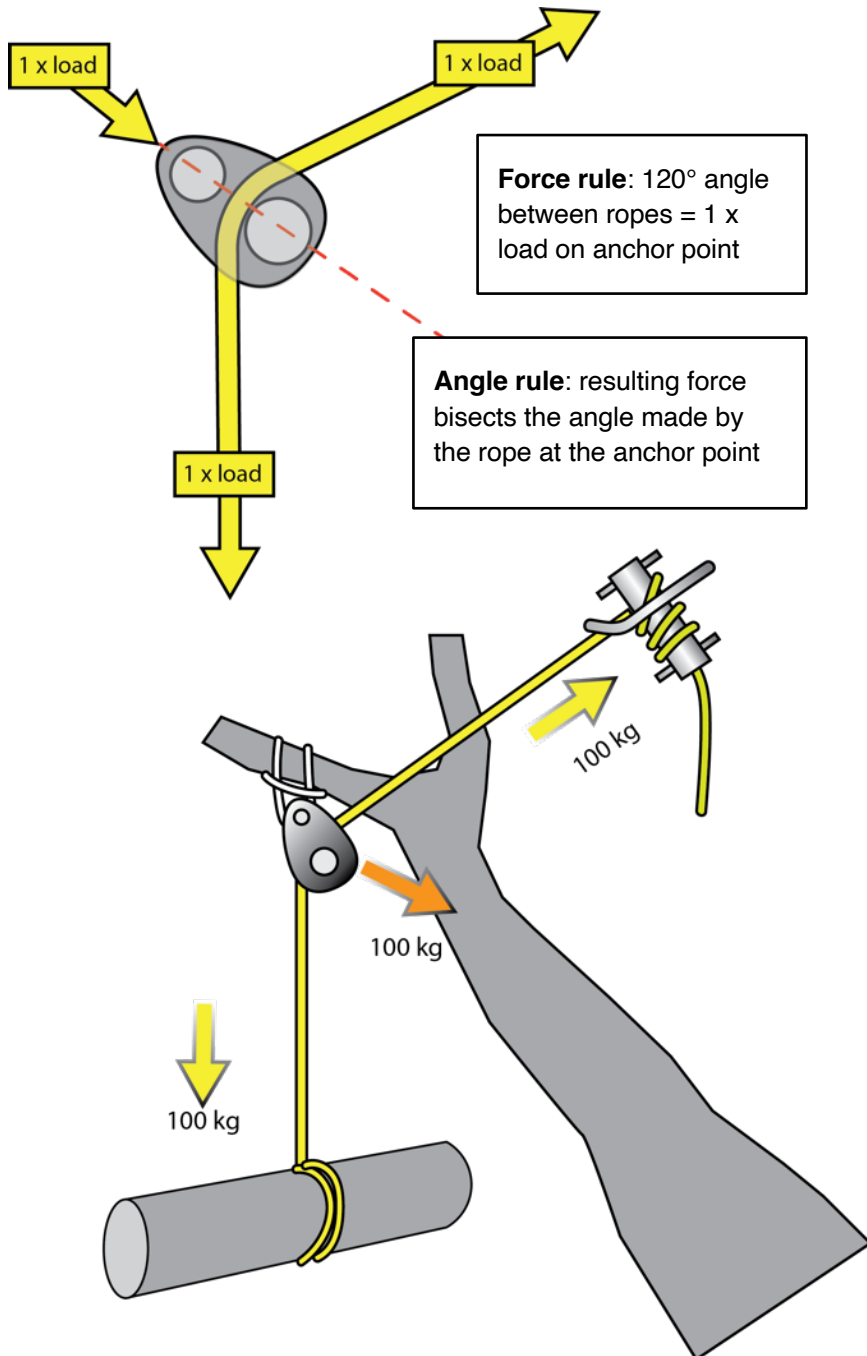
The wider the angle made by a rope passing over a point, the less force the rope applies to that point.

The two rules above may seem confusing at first but the examples on the following pages will show that they are fairly easy concepts to apply in practical tree work.





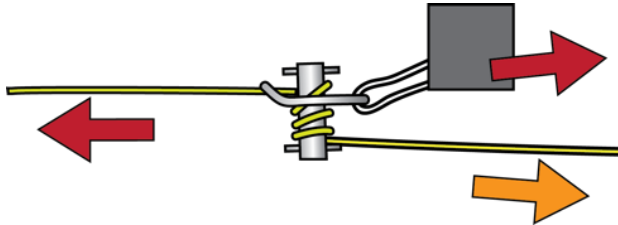




6: Friction

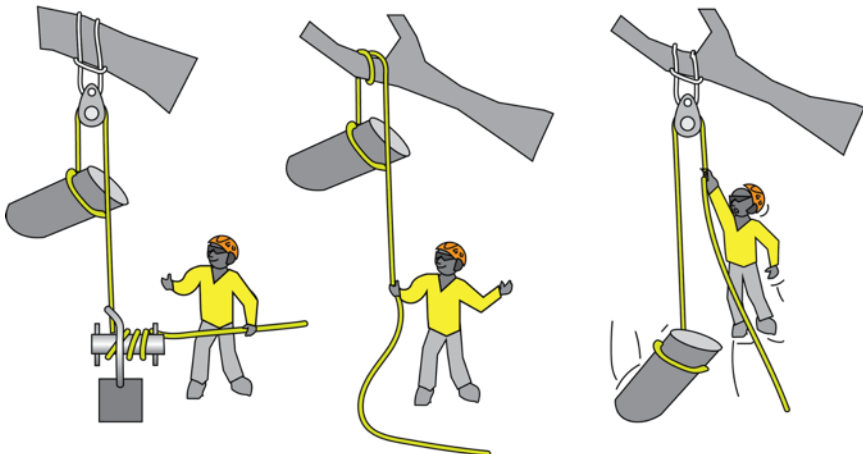
Wherever friction occurs in a system, it will reduce the force being carried by the rope from that point on.

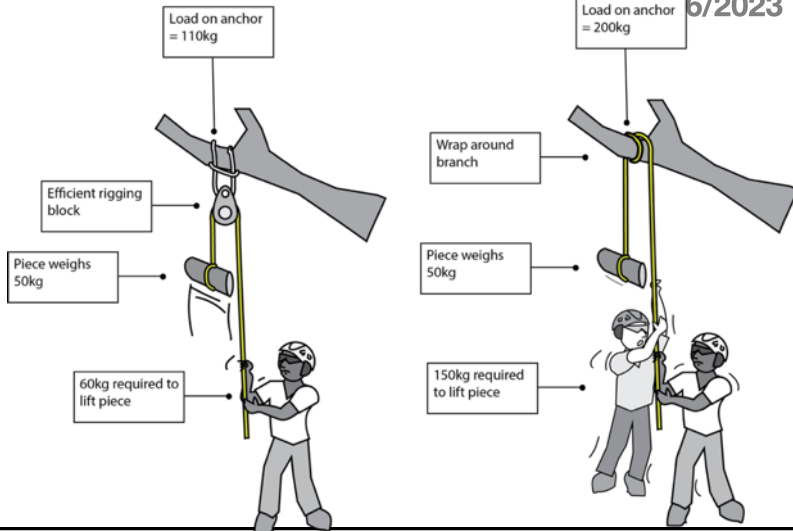
Most rigging systems will need to incorporate friction, at some point, in order to control the loads being rigged.



In the image above, a heavy load is being applied to the **lead** side of the rope on the left. Friction is applied at the Portawrap, which reduces the load being carried by the rope throughout the system from that point on (orange arrow). It's important to remember, however, that the force has to go somewhere – in this case it is being taken by the Portawrap anchor point.

The image below shows some examples of the application of friction in tree work and of the consequences for not applying it at all.





7: Friction at anchor points: the difference between lifting and lowering

Friction will occur at every anchor point, even when using the most efficient pulley or block. Friction works **against** whichever direction the rope is moved in – it will help to slow objects as they are lowered but it will make it more difficult to lift loads or pre-tension ropes.

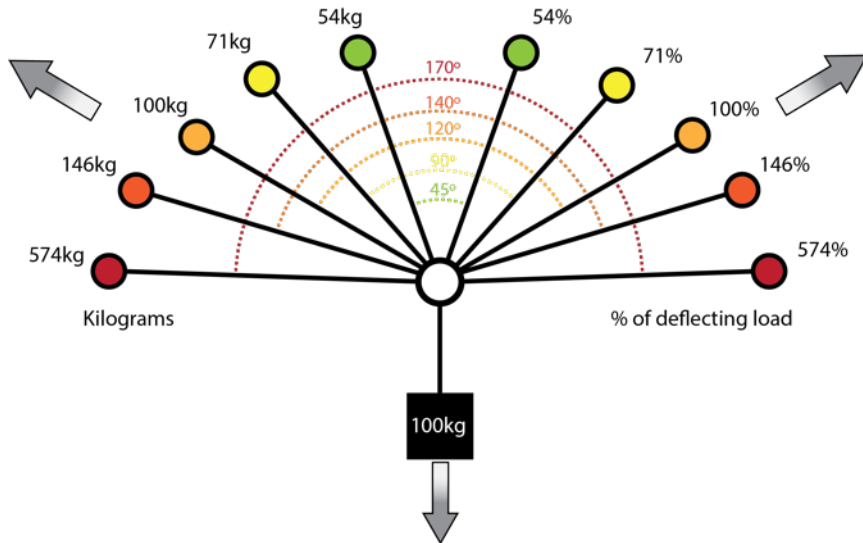
A rough description of the amount of friction in an anchor point is its **efficiency** – very efficient rigging blocks will have a small amount of friction, while natural crotch rigging points will have a large amount of friction. This does not make one better than the other – rather, each should be selected for its correct application.

The image above compares two lifting operations: in both a log weighing 60 kg is being lifted into the tree. It is important to note that:

With more efficient anchor points, less force is required for lifting.

With more efficient anchor points, less force is applied to the anchor point.

If the piece was to be lowered, the reverse would be true – the more efficient the anchor point, the more force must be applied to the fall of the rope to control the lowering. Applying friction at the anchor point can be an effective way of reducing forces on the anchor point.



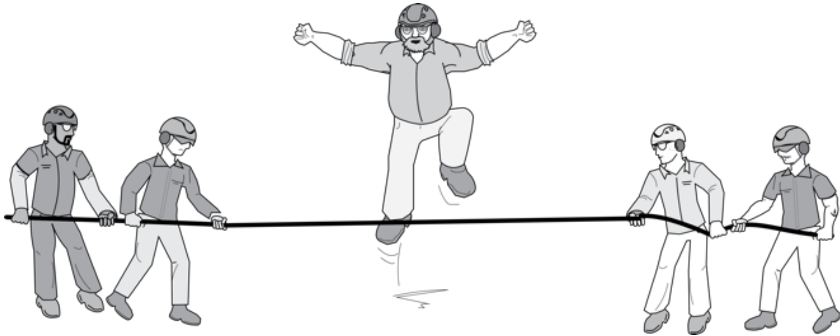
8: Deflection forces

Where a rope is anchored under tension and deflected in the middle (pulled sideways somehow) the force applied at each anchor can be five times or more, larger than the deflecting force. The straighter the rope, the larger this force will be.

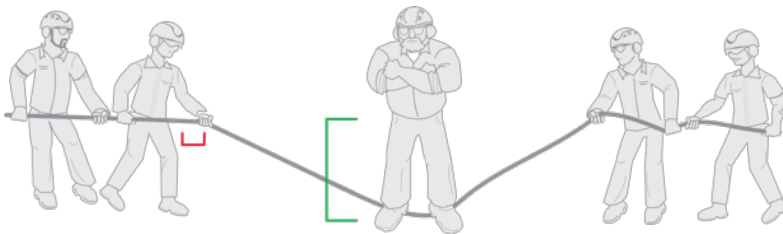
Deflection forces (in tree work) occur where a loaded rope makes an angle at a point. In normal usage the system is assembled (i.e. the angle is made) before the system is loaded. If the system is pre-loaded however, and then the deflection force is introduced, the resulting force that can be generated is enormous.

Why is deflection force so large?

In the image below, the four crew members are trying to keep the rope taut, while the crew leader jumps on to the rope in the middle



All of the crew members will be pulled into the middle.



Looking carefully at the distances involved, it can be seen that the distance the rope has been deflected sideways in the middle by the crew leader (green) is much larger than the distance that the crew members have been pulled in (red). Working out this ratio will show how much larger the force is at either end.



This shows a five to one increase in force. (Diagram not to scale)

In practical tree work this visualisation of how the forces work would be almost impossible to use. The distance that anchor points are pulled sideways can rarely be accurately measured, and even if they could, it is hard to know how much elongation there is in the rope – in the diagram above elongation has been assumed to be zero.

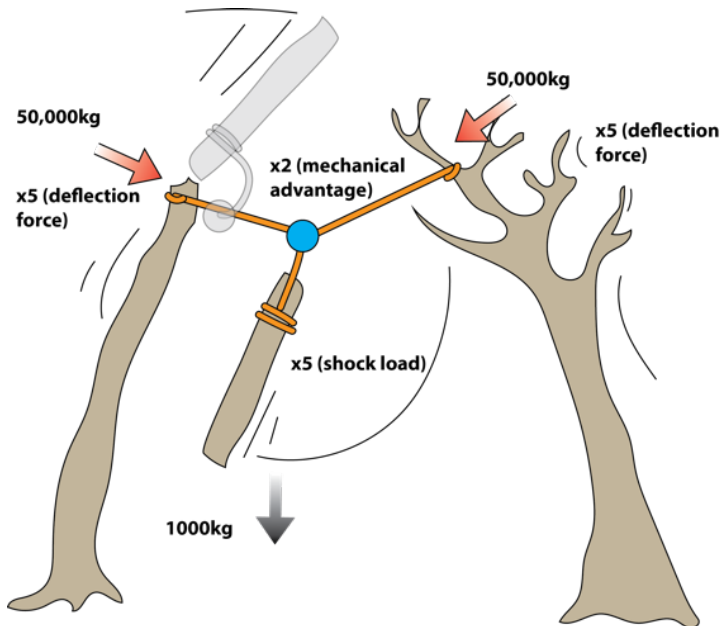
Techniques for accurately calculating deflection forces are given in **Appendix B: Working the angles.**

Deflection forces in tree work

Deflection forces are frequently generated during tree work and can be both a helpful tool and a dangerous enemy:

- When trying to put additional tension into a rigging line it is far more effective to deflect the line (tension it, then pull it sideways and capture the slack) than to pull it straight down into a rope brake.
- When using a tag line to pull a tree or branch, an effective way of applying tension is to pre-tension the line and secure it to an anchor, then deflect it sideways. Depending on elastic elongation, high peak forces can be generated.

- When using running-anchor or floating-anchor rigging, or any rigging situation where a tension line is deflected by a load, assume that force applied to the anchor points of the support line may be up to five times the load applied to the floating or running anchor. This multiplication takes place after the inclusion of shock load and mechanical advantage through the first anchor. For example:



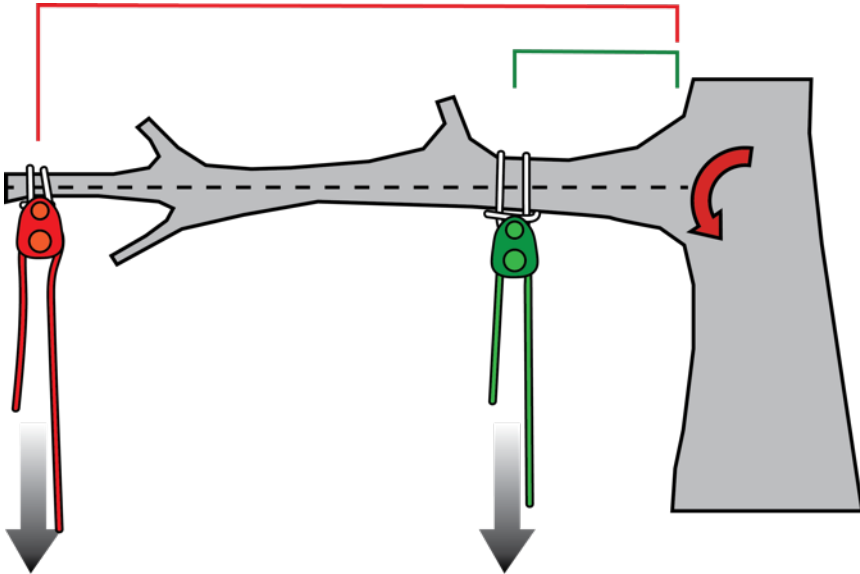
1000 kg piece x 5 (shock load) x 2 (mechanical advantage at floating anchor) x 5 (deflection forces in extremely static highline) = 50,000 kg applied at each anchor point.

Note that in this example, not only is the magnitude of the force applied extremely high, it is also applied in the worst possible direction – pulling sideways on the anchor point.

- Where a load is balanced using the cradling technique, and the two arms of line make a very obtuse angle at the join, the load carried in the lines will be much higher than with a more acute angle. (See page 162, Running anchor rigging)

9: Leverage

The component of force which is perpendicular to the lever is multiplied by the length of the lever.



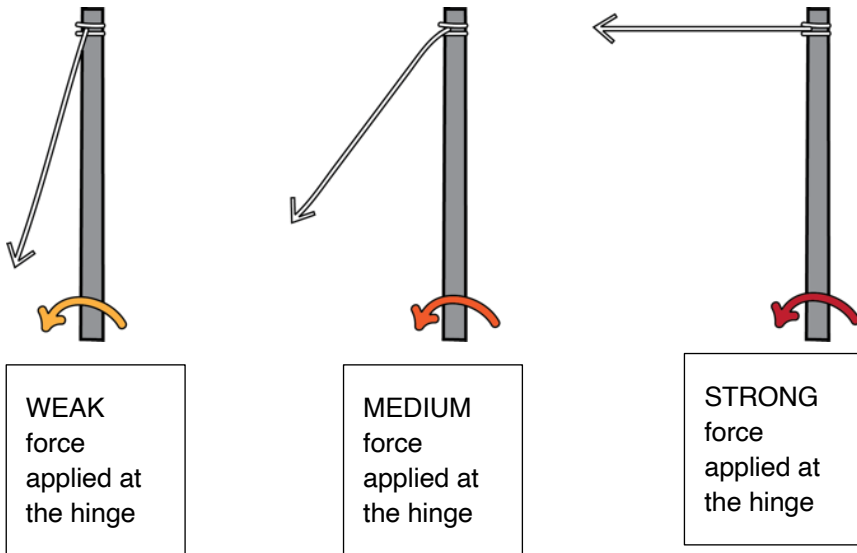
As working arborists should know automatically, one of these rigging points is probably alright for small loads and the other is positioned very badly. If the green system was used to rig a smaller load it would probably be OK ... whereas the red system is very likely to fail.

The difference is **leverage** – the multiplication of force by the use of a **lever arm**. The process would be familiar to anyone who has used a shovel, crowbar, high-lift jack or similar – or to any tree worker who has used a pulling rope to influence the direction of fall of a tree or tree part. This also helps to explain why tree branches are thick at the trunk and thin at the end and why trees are thicker at the base.

This means that, when pulling on a lever arm (such as when pulling a tree over using a rope), the more it is pulled directly sideways (perpendicular to the lever arm) the more **bending moment** will be applied.

In the images below, the coloured arrows at the base show how the bending moment applied at the base (see **Appendix B: Working the angles**) increases as the force is applied closer to perpendicular to the lever arm.

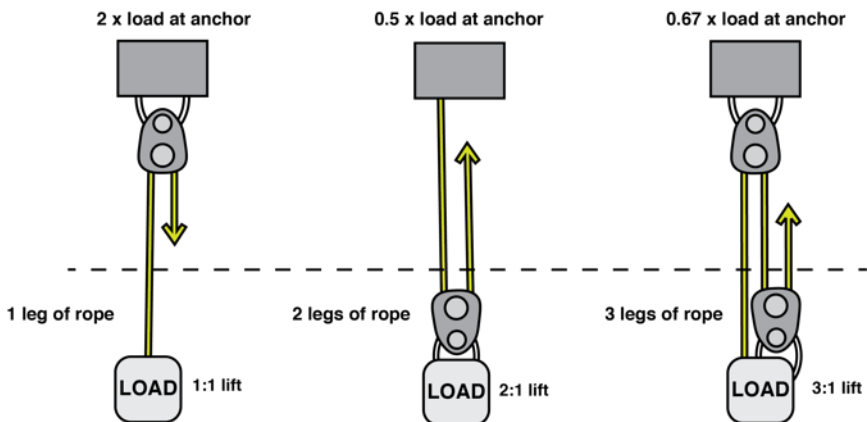
In each case, assume that the rope is being pulled with the same force.



10: Mechanical advantage

In simple mechanical advantage systems, count the number of legs of rope (also known as 'lines') that are either connected to the load or that are connected to a pulley that will travel at the same speed as the load.⁷

In compound mechanical advantage systems, calculate the mechanical advantage in each system first (as above), then multiply those numbers to calculate the total advantage gained.

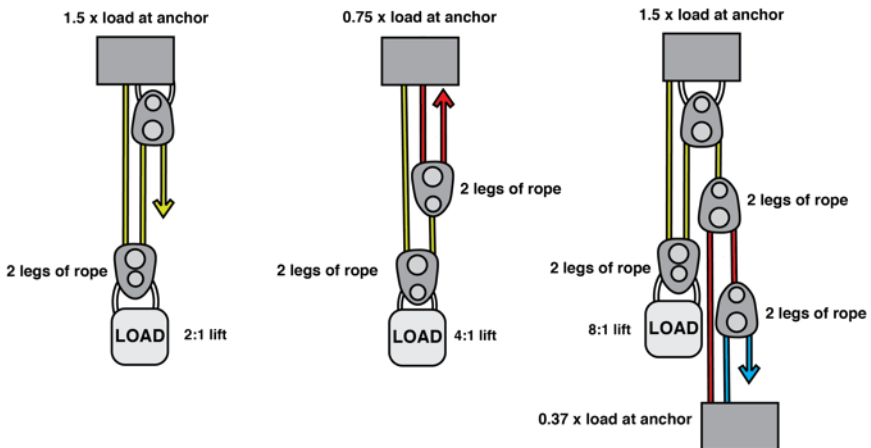


Compound mechanical advantage systems can be an excellent way to ‘step up’ the amount of advantage from a simple system. Install your most efficient pulley closest to the load – this will ‘multiply the efficiency’ throughout the system.

Compound systems are described as ‘one simple system pulling on another simple system’⁷.

A significant reduction in actual force will occur due to inefficiency at each pulley or block.

Methods of calculating mechanical advantage assume that rope legs will run parallel to loads and pulleys – separating rope legs will lose mechanical advantage.



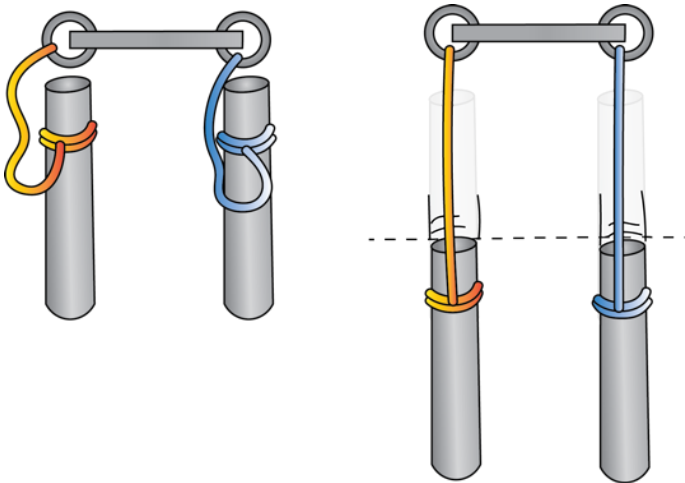
11: Shock load

Newton's second law of motion:

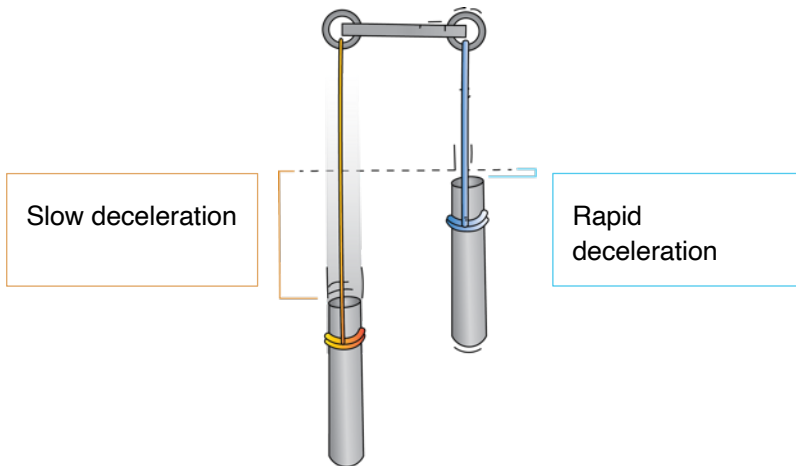
$$\mathbf{F = ma}$$

Force = mass x acceleration.

This rule affects many elements of tree work and of aerial rigging in particular. Consider the simple experiment below:



Two similar weights are dropped a similar distance. The image on the right shows the moment when the ropes that are securing the two pieces to the anchors above have just gone taut.



The orange line on the left is extremely elastic, and the load is brought to a stop over a long distance. The blue rope is ultra-static, and the load is brought to a stop almost instantly. In both cases the objects have the same mass and were travelling at the same speed, the only difference between the two is how sudden the deceleration has been.

It is quite likely that the sudden stop – the shock load – in the blue system will generate forces six to ten times greater than in the red system. This can break ropes, destroy rigging hardware and pull the heads out of trees.

If we want low forces to be generated, we can alter either:

- the **m** component: take smaller pieces; or
- the **a** component: don't bring things to a sudden stop; use stretchy ropes and let pieces run.

2: Dismantling trees

Tree dismantling is a complicated, multi-faceted mixture of art and science. Understanding the behaviour of tree parts during rigging operations, knowing the strength of tree structure and anchor points, and achieving good workflow, may take decades to learn properly.

Following methodical, careful practices and aiming for predictable outcomes is much more important than designing complicated rigging setups or falling the largest possible piece.

Performing works

Key safety information relating to site setup, tree inspection, tree access techniques and equipment, and practices for safe tree work are presented in the following Minimum Industry Standards:

- **MIS300 Safe Tree Work**
- **MIS301 Arborist Knots**
- **MIS302 Arborist Ropes**
- **MIS303 Tree Dismantling**
- **MIS305 Tree Climbing**
- **MIS306 Tree Inspection for Access and Work**
- **MIS315 Chainsaw Operations**

This document must be read in conjunction with the Minimum Industry Standards above to perform practical tree work tasks.



Good tree removal	Bad tree removal
Is planned well, with the correct rigging system or cut used for each piece, and alterations made to the system where necessary. Is sequenced well and each branch or section is removed in the correct order to clear space for the next piece. Is patient and unhurried, well-ordered and calm, taking sensible sized pieces. Is correctly paced to the processing capacity of the ground crew – taking smaller pieces if they are struggling to keep up. Is balanced well between faster recycle times (getting the line back and preparing for the next cut) and volume of pieces. Is communicated well, so that all crew members understand what is happening.	Is poorly planned, with pieces rigged into inappropriate systems. Is badly sequenced – effort is wasted with stuck branches, hangers and impacts between rigged pieces and remaining tree structure. Is hurried and chaotic, with piece sizes too large for good control. Is not adjusted to the pace of the ground crew – large pieces are sent down quicker than they can be dealt with. Sacrifices recycle time for volume, resulting in long waits for the aerial worker as ground crew struggle to process. Is badly communicated; misunderstandings result in mishaps and lost tempers, decisions are made in frustration and the crew loses focus.

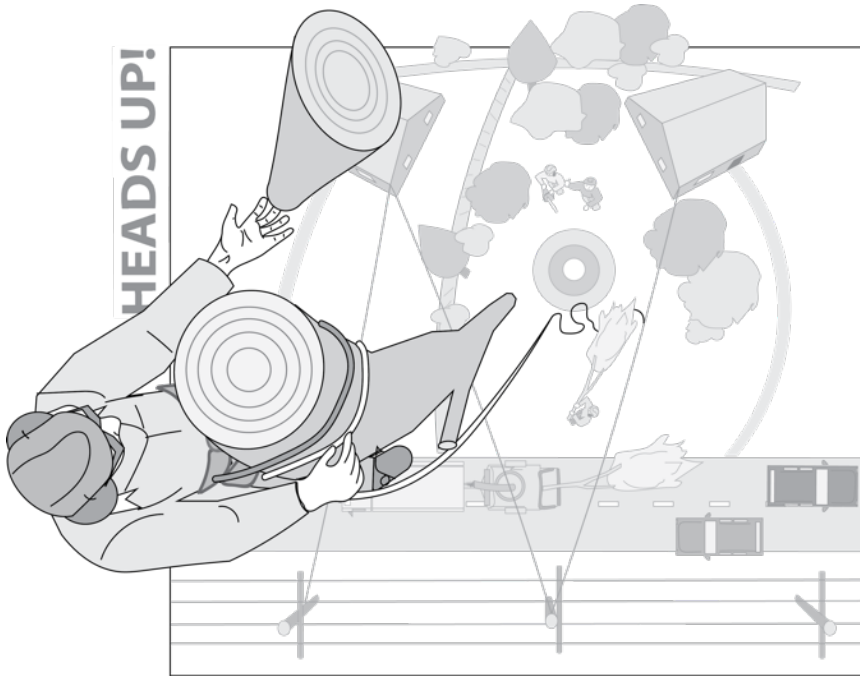
Good tree removal	Bad tree removal
Is conducted well, so that pieces hinge in the anticipated direction and run smoothly without becoming hung up; 'housekeeping' such as the removal of stubs is completed to avoid snags. Avoids shock loads and negative rigging where possible. Is set up so that pieces can be lowered into a clear and open area, allowing ground crew to process debris easily without unnecessary effort. Is collaborative, with good teamwork between the ground crew and aerial worker. Ropes are returned quickly, the site is kept clean, chainsaws are prepared and the next step of the job is anticipated.	Is conducted badly – cuts don't line up, pieces go the wrong way or get hung up, lines are pinched, property gets broken or crew members get hurt. Can put large and unknown forces on the tree. Can be fatal even when the tree worker is experienced – Dr Peter Donzelli, author of <i>The Art & Science of Practical Rigging</i>, was subsequently fatally injured while conducting rigging operations.

Tree workers must remember that **little mistakes often come before big ones**. If things are not working well on a job site – if little accidents keep occurring, crew members are frustrated and not paying attention, the aerial worker has lost their temper and made a few mistakes, it's getting late in the day and there is a temptation to take a shortcut ...



The work can always continue tomorrow.

Communication during tree work



Whenever a piece is cut, felled, dropped or thrown from the tree, or whenever there is a chance that anything will fall, it is critical for the aerial worker to ensure that all ground crew are paying attention.

It is easy to fumble logs or drop chainsaws or heavy rigging pulleys. Dropped objects can bounce off stubs, ricochet off the root plate, get tangled in branches or dislodge other material. If ground crew are paying attention, they can normally step comfortably out of the way.

Whenever on site, ground crew must remain constantly aware of what is happening in the trees above. An accidentally dropped rigging block could be just as fatal as a length of timber.

Use the **call-and-response** protocol each and every time.

Call-and-response protocol

Good, clear communication is vital on tree sites. During tree dismantling, poor communication or misunderstandings can have severe consequences. Machines are often running, workers become focused on their own roles, and it is easy for mistakes to be made.

Always ensure that good communication is possible: remember the call and response protocol:

- | | |
|-------------------------|------------|
| 1 Aerial worker: | Heads up? |
| 2 Ground crew: | All clear! |

If the response is not heard, **DO NOT PROCEED** with the planned work.

If communication is difficult or impossible, or if misunderstandings keep occurring, stop work until clear methods of communication are re-established.

Please see **MIS300 Safe Tree Work** for further details of communication methods commonly used on tree work sites.

Hand and whistle signals for use on tree sites

The following page provides hand and whistle signals for use when working on tree work sites.

The signals have been ratified by Arboriculture Australia Ltd and the New Zealand Arboricultural Association and are suggested for use as standard signals on all tree work sites.

HAND & WHISTLE SIGNALS FOR USE IN TREE WORK

heads up! or all clear! ground-crew to ground-crew  hand raised to warn climber not to cut	stop  1 short 	STOP  DANGER 1 short 
All clear to cut (ground crew signal to climber)  2 long make chopping motion with hand	pull harder on tag line or send up rigging or tag line  make gesture with both hands as if pulling rope	heads up! or all clear!  2 long
Fell (or drop) piece or section in this direction (ground crew signal to climber) 	hold rigging line taut or don't let it run  swing arm horizontally	send up chainsaw or bigger chainsaw required  join fists then simulate pulling starter cord of chainsaw
put this many wraps on the portwrap or bollard  hold up no. of fingers to show no. of wraps	lift up or add tension to line  2 short	lower down or let it run  1 long
turn off machine / stop doing that  simulate cutting throat with hand	hold taut then lower  swing arm horizontally then vertically	look at me or look at that  point at eyes then at object to attend to

**CREEP SPEED: USE HAND SIGNAL FOR MOTION WITH HAND
CLENCHING AND UNCLENCHING**

Using a chainsaw in trees

Operation of chainsaws on both the ground and in the tree is described in detail in **MIS315 Chainsaw Operations**. Please see that document for general principles of safe chainsaw operation.

When using a chainsaw to dismantle trees whilst climbing it is critical that two points of attachment are installed prior to making any cut. Where possible, the second point of attachment should be made to an anchor that would support the weight of the operator were the first attachment to be cut or to fail, although this is not always possible.

For the purposes of this MIS, a distinction will be made between a **life support attachment** (one which would hold the climber if necessary) and a **work-positioning attachment** (one which is used to maintain the climber's position in order to facilitate good chainsaw use but is not sufficiently large to support the climber's weight – for example while pruning a branch end or similar).

Attachment point configurations are listed below in order from most secure to least secure:

- **Two (or more) life support attachments; no possibility of contact with saw**

For example, both the climbing line and the lanyard are on the other side of a stem from the cut to be made or are on the other side of the climber's body.

- **Two (or more) life support attachments; very low possibility of contact with saw**

Where a cut is made on the other side of a stem from the climber's lanyard and line, or on the opposite side of the body.

- **One life support attachment; one work-positioning attachment, no possibility of contact with saw**

Where a cut is made on the same side as the climber's lanyard, or near the climbing line, but separation exists between cuts and possibility of contact is very low.

- **One life support attachment; one work-positioning attachment, any possibility of contact between saw and work-positioning attachment**

For example, where a cut is near the climber's lanyard. Avoid this configuration.

- **One life support attachment; one work-positioning attachment, any possibility of contact between saw and life support attachment**

Where a cut is near the climbing line and the lanyard is not suitable for life support. **Do not make cuts in this configuration** – change work position or install a new life-support attachment.

Before making any cut

Ensure that the answer to all of the following questions is a definite **YES before** making the first cut:

- ☐ **Are all components in any rigging system used correctly attached and configured?**
 - Check that previous rigging operations have not moved any components.
 - Ensure that all components will be loaded correctly and are not misconfigured.
- ☐ **Will the forces applied by the rigging operation be within the WLL of all components within their current configuration?**
 - estimate loads during the full range of movement of proposed rigging
 - consider whether components could become misconfigured if unloaded during dynamic rigging
- ☐ **Will the behaviour of the load during rigging be predictable?**
 - Will the piece hinge the way you want or are a tag line or wedges required?
 - Is the operator making the cut safe if the piece swings back?
 - Will the piece swing away from other branches and tree parts, and avoid getting hung up?
 - Are ground crew out of the line of swing?
 - Are ground crew and property safe if any dead branches are broken and fall?
- ☐ **Will the rigging system run freely without contacting any other equipment or structures?**
 - Are climbing lines or EWP parts safely away from rigging components?
 - Will the system swing free of other tree parts or structures?
- ☐ **Are ground crew ready for their roles in the rigging operation?**
 - Is the rope controller ready? Do they understand what will be required of them?

- Has sufficient tension been put into the rigging line?
 - Are other ground crew in the area attentive to the operation and ready to assist?
 - Is the drop zone free of other workers or members of the public?
 - Is the lowering zone free of debris and suitable to bring this piece down into?
- ☐ **Are you ready and able to make the required cuts in a safe manner and do you have a good body position?**
 - Will you be protected if the piece breaks early?
 - Will you be able to use the saw properly and make accurate cuts?
 - Will you be protected if the piece splits, barber-chairs or hangs up?
- ☐ **Will all components still be within the safety factor if the operation goes badly?**
 - While most operations run smoothly, you should not rely on the piece being rigged away from you or on it being brought to a stop smoothly. Plan for the worst!

If the answer to any of these questions is **'No'**, or **'Maybe'** then



Find another way of doing the work.

Recognising that a task is outside of an operator's competence can be one of the most challenging aspects of tree work. A high proportion of serious injuries occur within the first two years of an arborist's career – when they are injured by something they couldn't anticipate.⁵

A component of successful tree work that is often overlooked whilst learning is the tree worker's ability to execute what he/she is trying to achieve. As workers gain skill their capacity to achieve complex tasks in a tree increases. A competent professional can recognise the limits of their capacity to execute a complex plan, and will not exceed those limits.

Cut sequences and techniques – branches

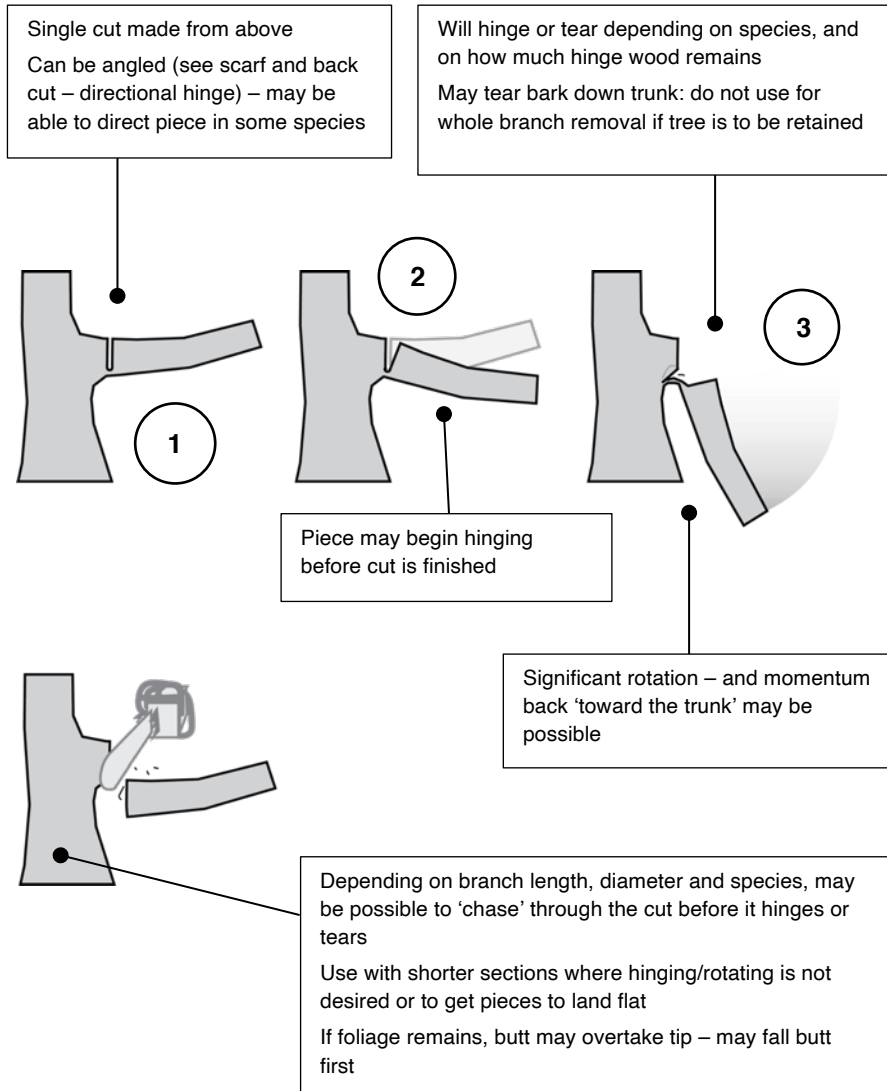
The following cut-behaviour diagrams are intended to demonstrate some of the relationships between cut sequence and placing, and the subsequent behaviour of the cut section.

Different tree species, foliage weighting, section diameter, weight and length will all affect the behaviour of the cut piece and should be considered when deciding on cuts to be used and on cut directions.

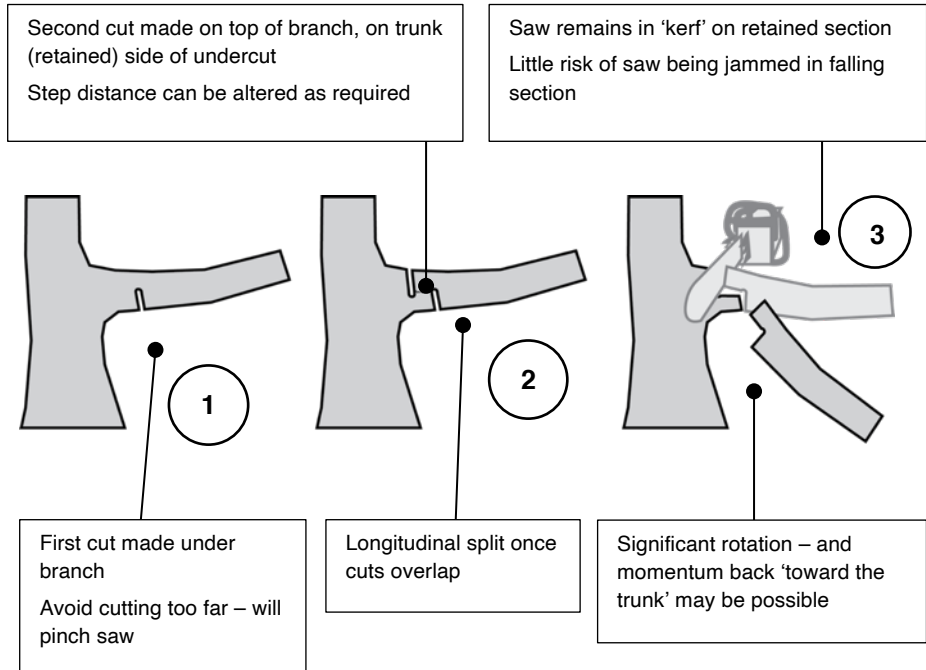
Many variations of these cuts exist; this is not intended to be an exhaustive list, and elements can be mixed and matched as required to achieve the desired outcome.

Try to **ensure that cuts are made accurately** even in situations where it is not required – practice makes perfect and aiming for perfect every time will make it much easier to achieve perfection when it is needed: success becomes habitual.

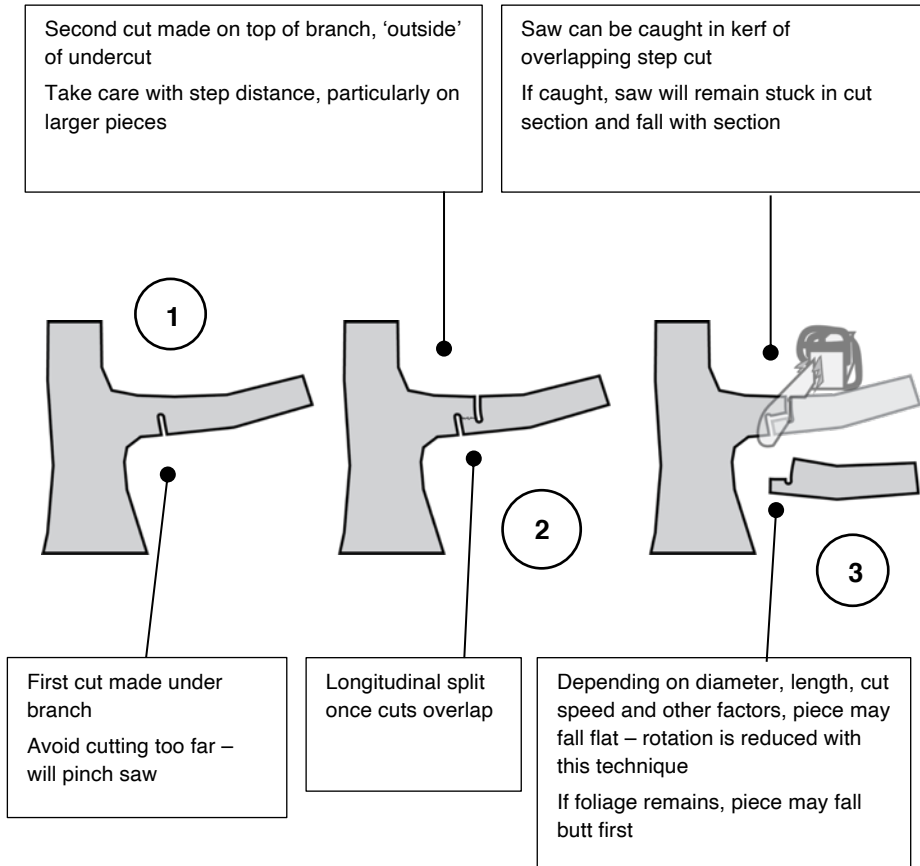
Straight back cut



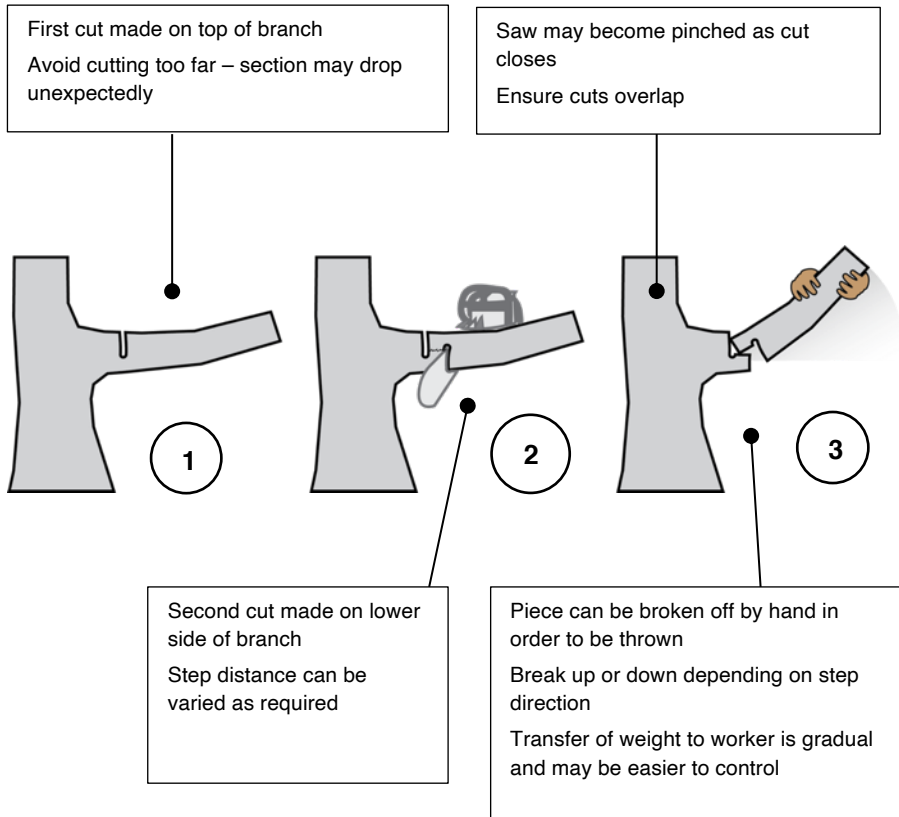
Step cut – undercut made first – top cut inside



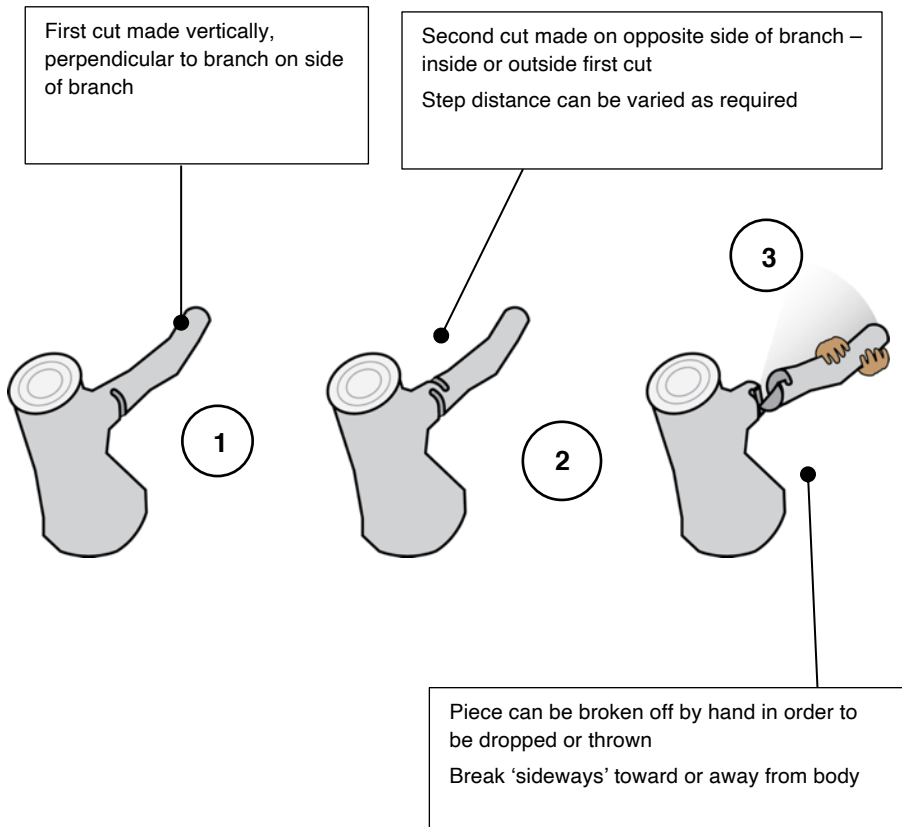
Step cut – undercut made first – top cut outside



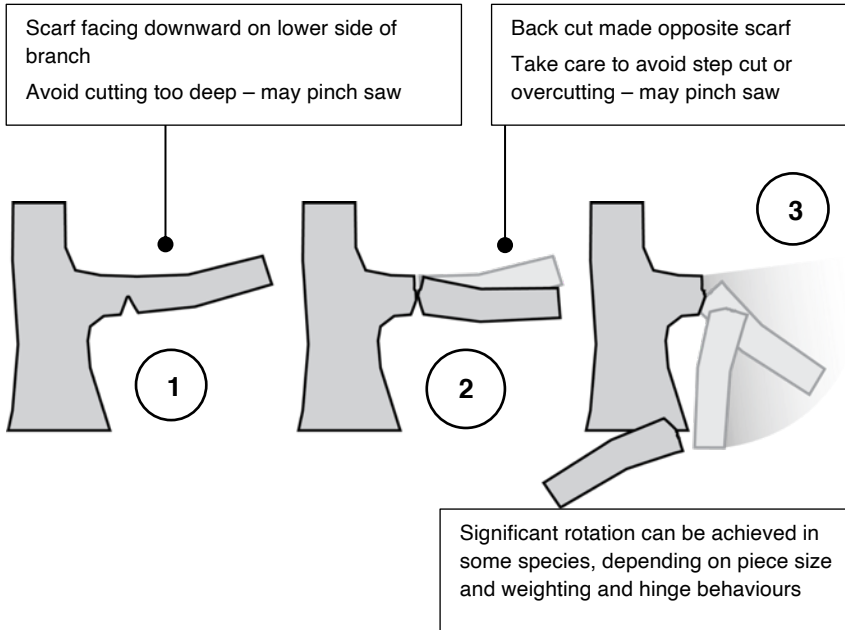
Step cut – top cut made first



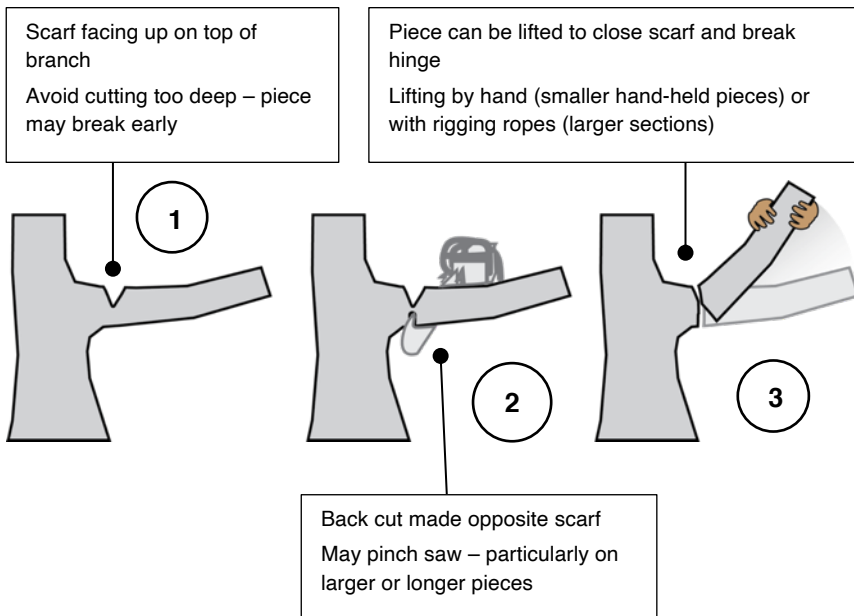
Step cut – lateral cuts



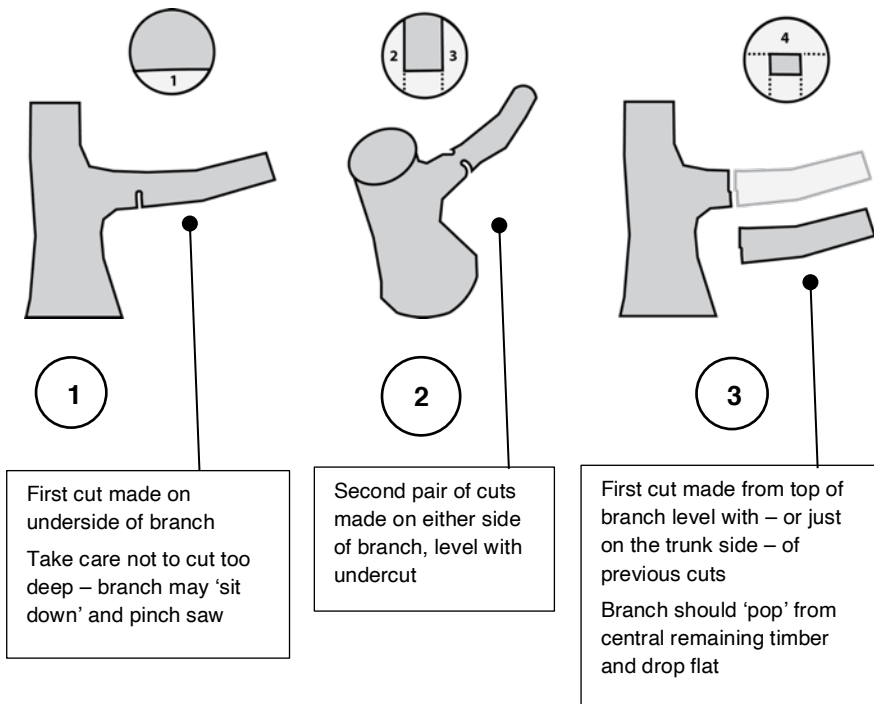
Scarf and back cut – downward



Scarf and back cut – upward



Box cut



The box cut is a sequence of cuts used to reduce the rotation of limbs as they are cut. In some species this technique will result in clean 'pops' of branches, which will initially fall flat.

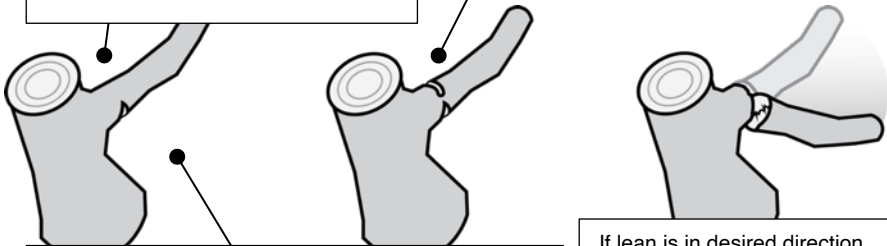
Care must be taken that the piece does not break early, during the initial three cuts, or pinch the saw while installing these cuts.

Putting a wedge or slice of wood into the lower cut after it is made may help to prevent pinching and assist the branch to drop flat.

Scarf and back cut – directional hinge

Scarf cut at angle on side of branch (approximately 45° depending on weighting, species and desired behaviour)

Back cut made parallel to scarf
Extra hinge may be retained on top side if necessary



Degree to which scarf angled around branch, will determine direction of hinge

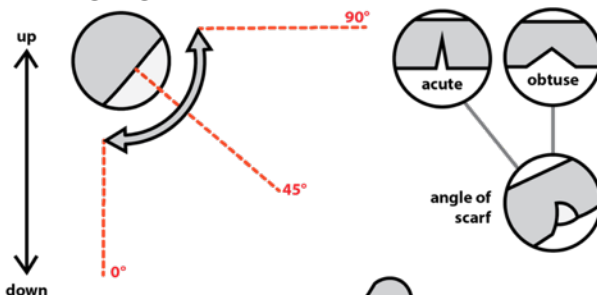
Placing scarf too vertically on branch (past 45° on many species) may result in failure of hinge

Different species, intended behaviour, branch weighting and other factors will require different scarf angles

If lean is in desired direction and hinge does not fail, branch will initially follow hinge

Hinge control will be retained for longer in some species, in others hinge will fail rapidly, and piece will fall before achieving significant lateral swing

cross section of branch showing facing of scarf



More obtuse scarf cuts may allow branch to follow hinge for longer in some species

Using a tagline or rigging techniques may assist in ensuring that cut section follows hinge – particularly where foliage may catch wind or lean direction is uncertain



cross section of branch showing scarf and back cut

When back cut is placed, section will follow hinge if centre of gravity (including any applied force) is on scarf side of hinge, and if hinge is strong enough to prevent downwards failure

Cut sequences and techniques – tree heads and timber

The cut behaviour diagrams on the following pages are intended to demonstrate some of the relationships between cut sequence and placing, and the subsequent behaviour of the cut section.

As before, different tree species, foliage weighting, section diameter, weight and length will all affect the behaviour of the cut piece and should be considered when selecting cuts to be used and cut directions.

A tag line or felling wedges should be used wherever the natural lean of the piece cannot be ascertained. Tree workers must avoid just cutting the hinge smaller and smaller – eventually the piece will fall, but it may not be in the intended direction.

Falling the head out of a tree

Angle and type of scarf will affect behaviour of head

More obtuse scarfs may allow longer hinge control of head during felling

Scarf angle may affect fall of head (butt first/tip first) in some species

If centre of gravity of piece is on scarf side of hinge and hinge strength is sufficient, piece will follow hinge initially

Duration of hinge control will depend on species of tree, lean and weighting, wind, any rigging or taglines used, width of hinge and type and angle of scarf

If necessary, use taglines or pulling ropes to influence lean or prevent sideways failure

If centre of gravity of piece is on scarf side of hinge and hinge strength is sufficient, piece will follow hinge initially

Duration of hinge control will depend on species of tree, lean and weighting, wind, any rigging or taglines used, width of hinge and type and angle of scarf

If necessary, use taglines or pulling ropes to influence lean or prevent sideways failure

cross section of stem showing angle of scarf



cross section of stem showing facing of scarf



cross section of stem showing scarf and back cut



cross section of stem showing step up of back cut

Consider the use of wing or 'kerf' cuts above scarf and back cut if there is a risk of fibre tears impacting climber attachments

Cutter should try to stay to side or at 45° on the tension side of any lean

Avoid being to rear of stem – if stem splits (barber chair) it will impact workers directly to rear

Use directional felling techniques

Ensure **back cut is stepped above scarf** to prevent head from slipping back across cut

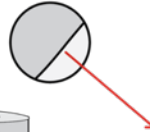
Head will push backwards strongly against stem as it falls

Falling sections of timber

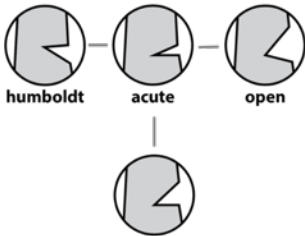
When falling sections of timber from the tree, significant control over falling behaviour of section can be achieved by varying length of section taken, and angle and type of scarf.

When snatching or felling sections out of a tree, the main climbing line should usually be removed before the scarf is cut. This prevents accidental failure or cutting of the section with the climbing line still installed.

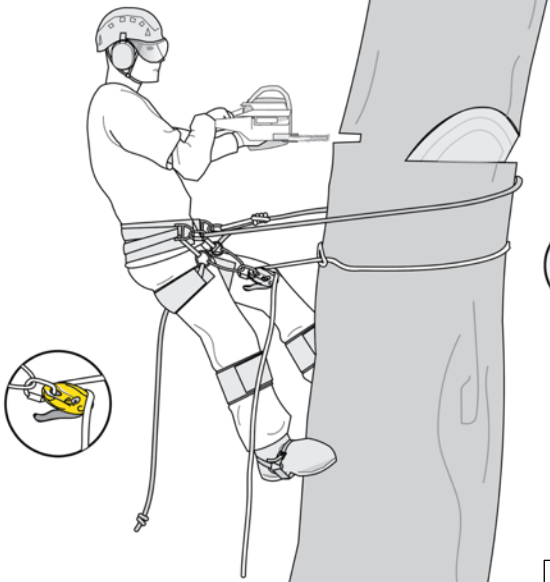
cross section of stem showing facing of scarf



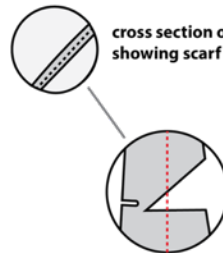
cross section of stem showing angle of scarf



The use of tag lines to induce lean will allow larger hinge thicknesses to be left



cross section of stem showing scarf and back cut



centre of gravity of cut piece

If practical, consider installation of one point of attachment in 'prepared to self-evacuate' configuration.

In an accident, this will make self-rescue much easier.

When falling sections of timber from the tree, cutting a deeper scarf can help to ensure that the centre of gravity of the cut section is in front of the hinge, reducing the need for pushing or the use of taglines.

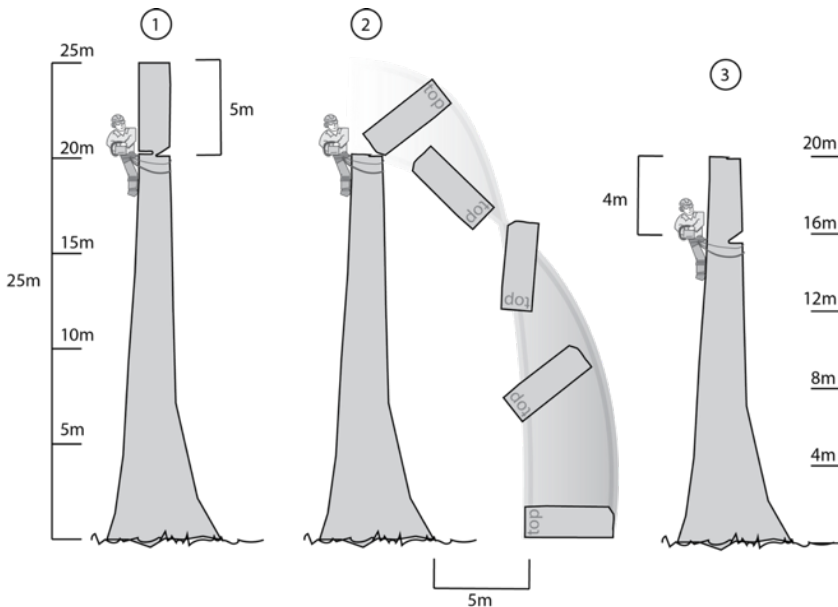
Falling sections of timber – landing sections flat

In some tree work environments, it may be possible to fall longer sections of timber, providing the behaviour of the section is predictable on impact with the ground.

According to *The Fundamentals of General Tree Work*, by American arborist Jerry Beranek⁸, the degree of rotation of a cut section will depend on the length of the piece taken and the angle and depth of the scarf.

Working in softwoods, Beranek determined that, using a 45° scarf placed 1/3 of the way into the stem, cutting the top 1/5 (20%) of the remaining tree height would get the section to land perfectly flat.

In the example below, the climber is sectioning down a 25m high stem. One 5th of 25m is 5m, so the first cut is made at 20m ($25\text{m} - 5\text{m} = 20\text{m}$)



The piece will land flat, approximately its own length (5m) out from the trunk, with the top facing back toward the trunk. The stem is now 20 m high.

One 5th of 20m is 4m, so the next cut is made at 16m ($20\text{m} - 4\text{m} = 16\text{m}$).

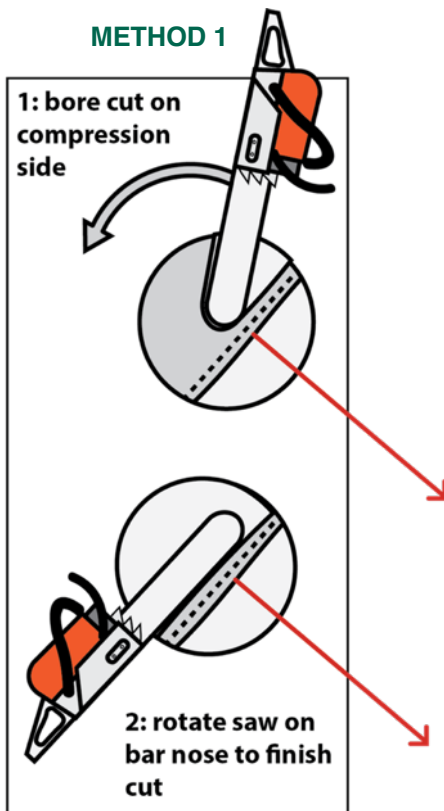
Beranek also determined that **removing the top 1/3 of the tree** (cutting at approximately 17 m instead of 20 m in the first image) **will result in the piece landing exactly on its tip.**

With practice, these two results can be altered to some degree by adjusting scarf angle to gain more or less rotation. Experienced climbers can normally predict the fall of dropped sections with a high degree of accuracy, whether by using Beranek's method or through years of practice.

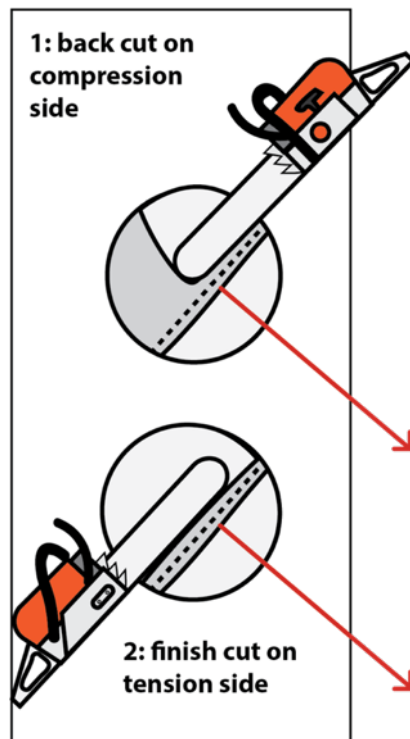
Tree workers unfamiliar with these techniques are advised to practice in trees where the result is not critical before relying on their ability to predict the results of dropped sections.

Cutting techniques where trunk diameter is greater than bar length

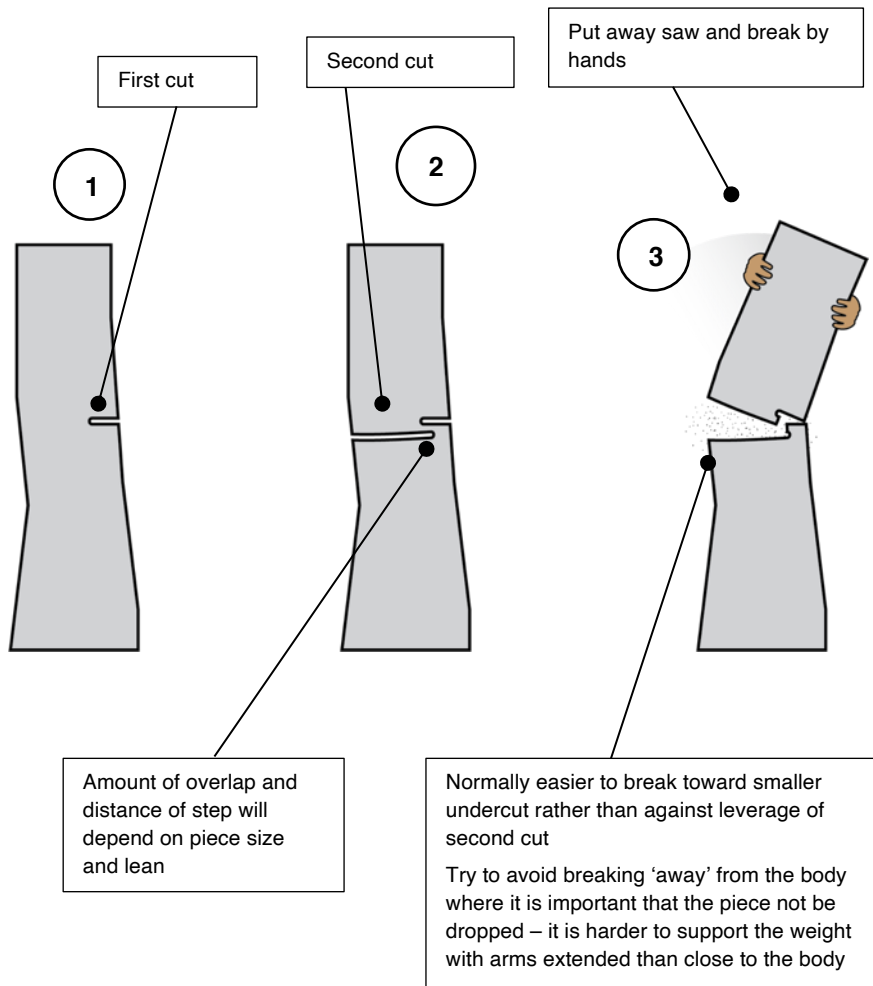
METHOD 1



METHOD 2



Blocking down: step cuts on timber



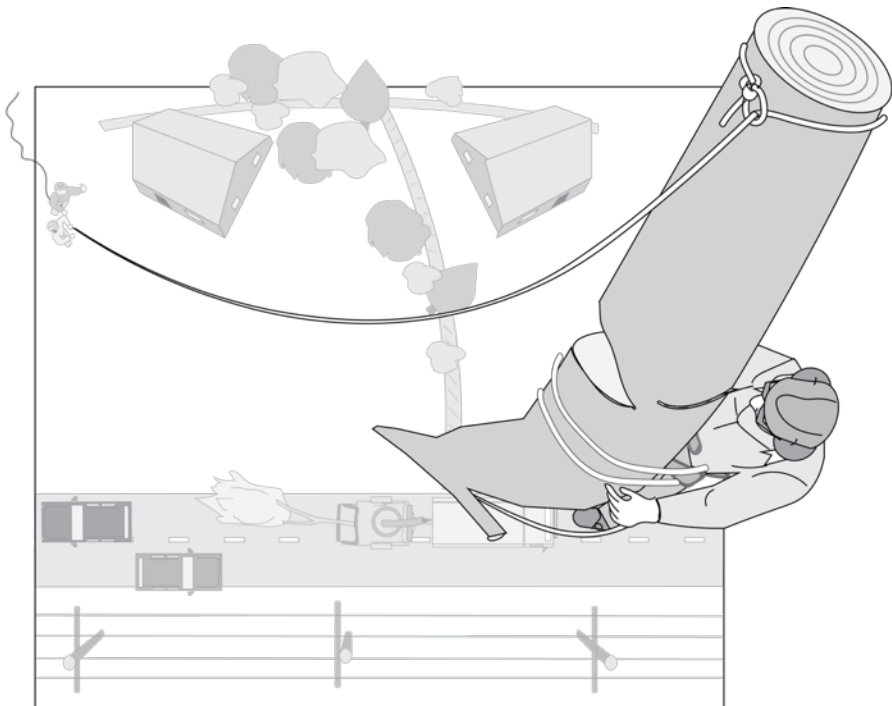
Falling techniques for tree dismantling – use of wedges and taglines

In most respects the techniques used to cut and free-fall sections of tree during dismantling operations are no different to those used when falling and cutting trees at ground level. Techniques described in:

MIS315 Chainsaw Operations

can usually be applied when working at height.

In particular, the use of wedges or taglines should be considered whenever the lean or weighting of a branch, head or section of timber is uncertain. Where mistakes are made and tree sections fall in the wrong direction, it can be much harder to avoid being hit by the piece when working at height.



Rigging operations

Previous sections have considered the use of a chainsaw while dismantling trees, as well as cuts and techniques to achieve desired outcomes when hand-holding or free-falling pieces from a tree.

Many of these techniques will still be used when conducting rigging operations – and in some cases the initial behaviour of the cut pieces will not significantly change.

In other rigging setups, however, the attachment point of the rope, the angle of rope to the first anchor point, and the degree of tension held in the rope, can all exert a high degree of control on the behaviour of the rigged section.

During any rigging operation, the following factors can be controlled:

- Which piece will be cut?
- Which rigging system will be used to control it and where will the anchor points be?
- Where on the piece will the rigging system be attached?
- What cut will be used and what angles will the cut be made to?
- What control will be applied to the rigging rope during the cut and after the load is separated from the tree?
- What work position will the worker be in to ensure their safety whilst rigging?

The interplay of these factors will determine the behaviour of the rigged load. Mastering these factors will result in good control over the rigged load.

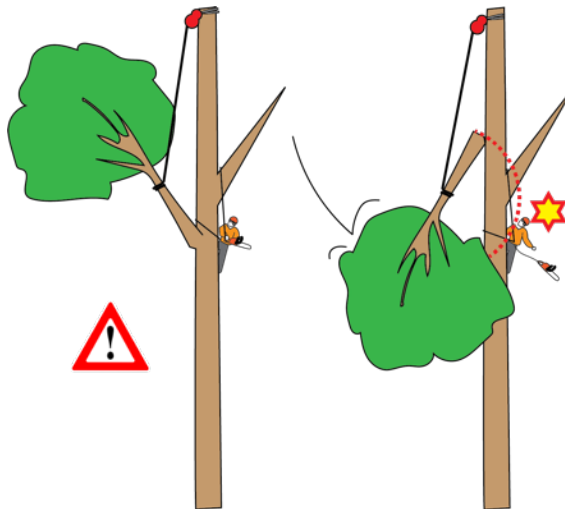
Rigging attachment point: cut and behaviour

The decision on where to site the attachment point will strongly influence the behaviour of a cut piece.

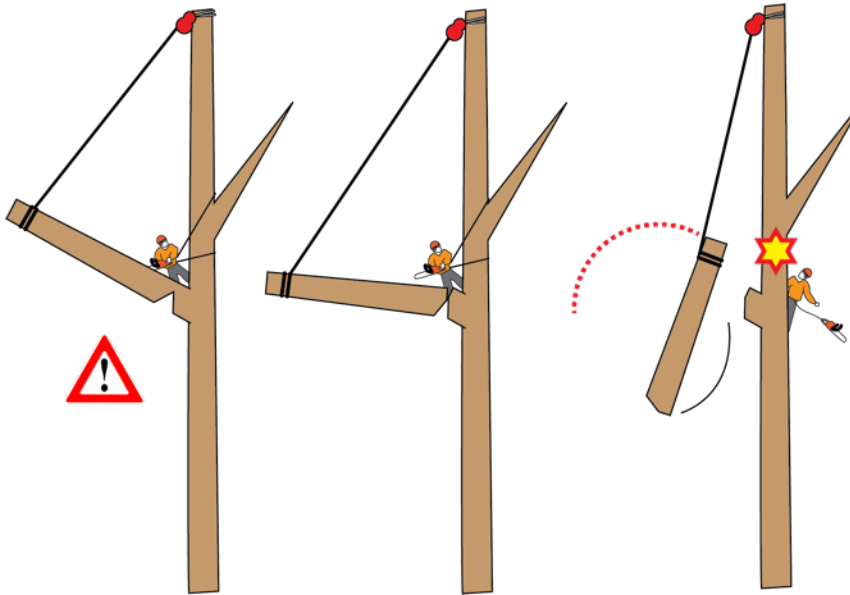
In any rigging operation, the variables which can be controlled are the position of the anchor point(s), the way in which the rope is attached to the piece, the size of piece taken, the cut used, and the way in which the rope is managed during the operation.

Different trees present with different architecture and different obstacles underneath them; a wide variety of rigging techniques may be required. It is critical that the crew is familiar with each technique, can clearly foresee what will occur during the operation, and has considered what will occur should the operation not go smoothly.

For example, what will happen during a rigging operation if the ground crew does not let the rope run, or if the rope binds onto the rope brake?



The image above shows the potential consequences of tying on to a branch just below the centre of gravity. When the hinge breaks, the piece will invert, potentially striking the climber unless the ground crew have managed to let the rope run sufficiently for the piece to be clear.

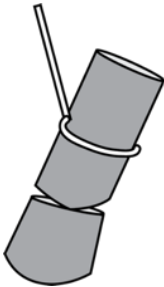
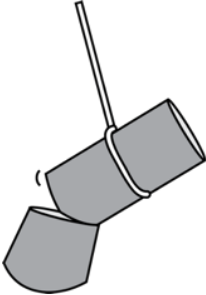
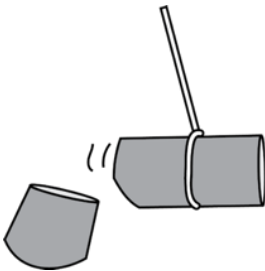


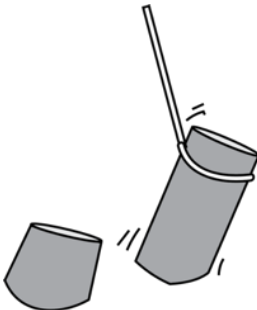
This sequence of images shows the potential consequence of tip-tying a lateral branch. In the second image, the ground crew have lowered the piece enough for the scarf to partially close. When the hinge breaks, the butt will drop and the section will swing violently back into the trunk.

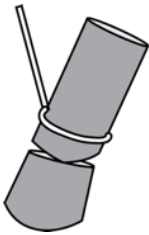
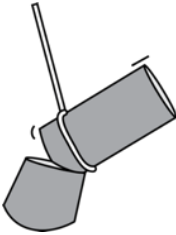
Rigging diagrams

The following pages show some examples of different rigging processes and attachment points. The enormous range of possibilities for different rigging systems, rope angles, piece lean and weight and rope control makes a comprehensive list impossible. The best way to learn is through experience, training and mentorship. Any of the rigging processes shown can be extremely dangerous if used in the wrong situations.

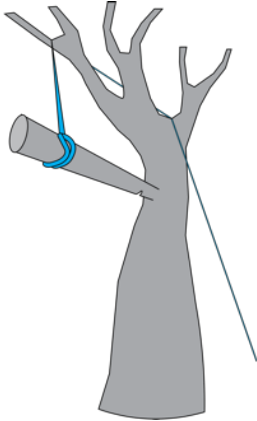
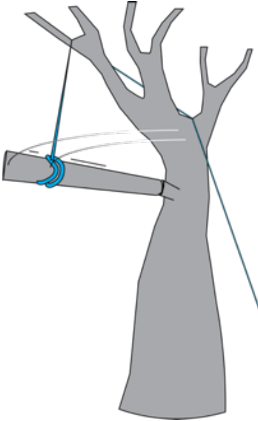
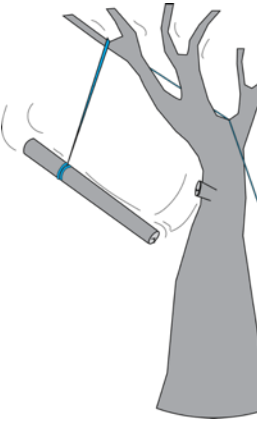
Rigging upright sections

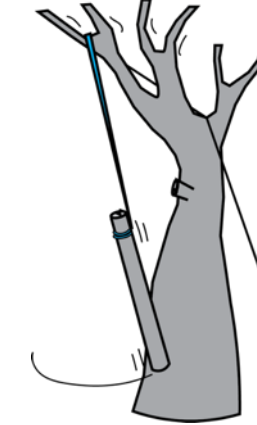
Rope attached to mid-point (centre of gravity) of upright section; piece scarfed across rope angle		
Scarf still closing	Hinge breaks	Piece falls away
		
Moderate to no rope control over hinge – will only assist if rope approach angle is closer to perpendicular than shown.	Rope should come into full tension exactly at the moment hinge breaks – aim for smooth transition between hinge and rope. Shock load is minimised.	Transfer from hinge to rope should be smooth. Piece will not lose height – ensure tree worker is protected from back swing or ensure piece is lowered.

Rope attached to tip of upright section (tip tied); piece scarfed away from rope angle		
Scarf still closing	Hinge breaks	Piece falls away
		
Depending on rope angle, some slack may need to be introduced to allow scarf to close.	Slack may need to be introduced to allow scarf to close. When hinge breaks, bottom of section will drop, shock-loading system . Rope control will affect hinge behaviour – can be used to influence lean if direction suitable and sufficient tension can be applied.	Section dropping as it separates from parent stem may generate significant shock load. Piece will lower butt first. NOTE 1: Using this technique as shown may generate large and unnecessary shock loads on the anchor point and rigging system. NOTE 2: As can be seen in the image, if the rope is held taut the section will remain at or above the height of the aerial worker. If the section is not lowered it may impact the aerial worker.

Rope attached to base of upright section (butt tied); piece scarfed across rope angle		
Scarf still closing	Hinge breaks	Piece falls away
		
No control of rope over hinge.		Section will invert – shock load generated by change in height of centre of gravity during scarf closing before rope ‘takes the load’. Piece will lose height – if rope elongation is incorporated, will almost certainly be below operator making cut.

Rigging lateral sections or branches

Rope attached to tip of lateral section or branch (tip tied)		
Scarf still closing	Hinge breaks	Piece falls away
 Good support provided to branch. Branch will follow direction of scarf if branch weight and rope pull are on correct side of hinge. Increased tension in rope will affect direction of fell.	 Branch supported across arc of rope until hinge breaks. Rope control can influence behaviour. Allowing slack will cause hinge to break sideways, possibly before scarf is closed (depending on species). Increased tension in rope will support branch further.	 Branch behaviour will depend on rope control. Allowing slack at correct moment in swing will make for smooth transition. Butt dropping will generate shock load if rope is held taut. As can be seen in the image, if the rope is held taut the section will remain at or above the height of the aerial worker. If the section is not lowered it may impact the aerial worker. Holding the branch up may result in the butt dropping and the tip impacting the aerial worker.

Rope attached to butt of lateral section or branch (butt tied)		
Scarf still closing	Hinge breaks	Piece falls away
		
No support provided by rope to branch. Branch will initially follow hinge if scarf is in direction of lean. Behaviour of branch will depend on cuts, species, weight, lean etc.	Depending on scarf direction, section weight, lean, tree species and other factors, branch may follow hinge until scarf closes or may break early. Will not significantly tension line as scarf closes.	Piece will drop entirely below cut. This can protect the aerial worker – will be unlikely to hit worker even if line is locked off and piece swings back. Avoiding shock load will rely on good rope control and smooth deceleration. Piece will be lowered tip first.

Rope control during rigging operations

Once the hinge or other cut breaks and the piece is separated from the parent stem, it's behaviour and trajectory will be under the control of the rigging rope or ropes.

It is important that the correct amount of friction has been added:

- If too little friction is incorporated into the system, it may be very difficult or impossible to control the load. This may result in dropped branches, damage and injury.
- If too much friction is incorporated into the system, the load may be impossible to lower. In negative rigging situations it may be impossible to avoid significant shock loads.

The correct amount of friction should be applied to achieve the desired rigging operation. Getting this right will not always be easy, because the interplay between rope diameter and construction, friction at brake, friction at anchor points and peak force of rigging operation, takes a lot of experience to reliably anticipate.

It is always better to err on the side of caution. If unsure, **take smaller pieces!**

Rope control: rope brakes and friction management

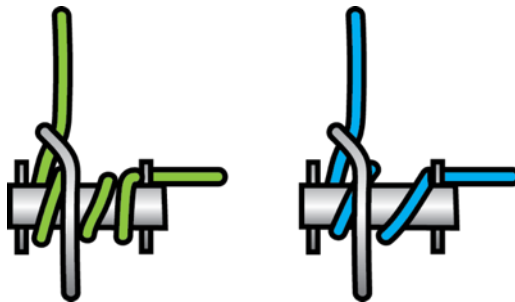
Friction can be applied at any suitable point in the rigging system.

The technique of applying aerial friction has been discussed on page 43 (Rope brakes), as well as within the particular rigging system design diagrams. Please also see page 138 (Applying friction at the point of cut) for a more detailed discussion of that technique.

This section will look at the correct use of **ground-based rope brakes**.

When using most rope brakes, additional friction is applied by increasing the number of turns or wraps of the rope around the device or tree part. This will sometimes be communicated from the aerial worker to the ground crew applying the friction but experienced ground crew can often anticipate the correct amount of friction to apply through their own estimation of the intended load.

Ensure that all crew members understand and use the same terminology for the use of any rope brake. Miscommunications can have more severe consequences than anticipated: the image above shows two Portawraps, both correctly configured. Some tree crews include the initial bight passed through the guide loop on the left when counting number of loops and some don't.



So some crews would say that the left-hand Portawrap has 3 wraps, and some would say 2.

Some crews would describe the right hand (blue) Portawrap as having 2 wraps, and some would say it only has 1.

Different devices secure the initial wrap in different ways. As such, it is recommended that **all wraps are counted when communicating about rope brakes**:

number of wraps = number of complete 360° turns that the rope makes around the anchor which the rope will fully retain during the operation.

So natural crotch rigging where the rope simply passes over a point or branch would be described as zero turns, even though the rope might be making contact with 270° of the branch. In the image above the green rope would be making three wraps and the blue rope would be making two wraps.

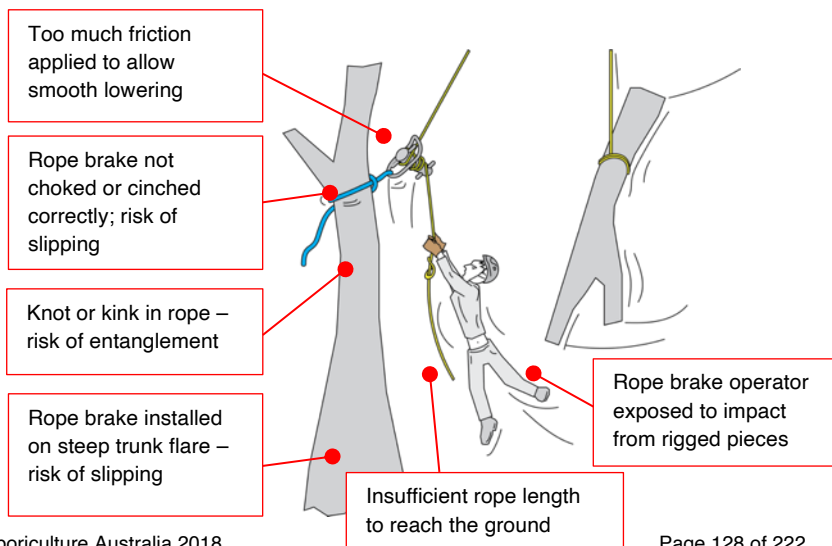
Half-wraps can also be described if required for accuracy.

Installing rope brakes

Ground-based rope brakes should be installed to solid anchors which are securely fixed, such as the base of the tree which is being rigged, or the base of an adjacent tree. The installation of rope brakes to other structures – such as vehicles or machinery – can also be part of some rigging systems.

Some considerations for rope brake installation:

- Will the rope brake be easy to access for the operator?
- Will the operator be exposed to hazards such as dropped or falling timber?
- Is the rope brake anchor strong enough for the intended use?
- Will the tensioned rope run correctly through the device or will a fairlead be required?
- Can the rope brake be installed firmly and securely – does it need to be ‘cut in’ to the anchor to prevent slipping?
- If mechanical advantage will be required, can it be installed easily when necessary?
- Will the fall side of the rope interfere with rigging operations?
- Will the operator have a clear line of sight to the aerial worker conducting rigging?

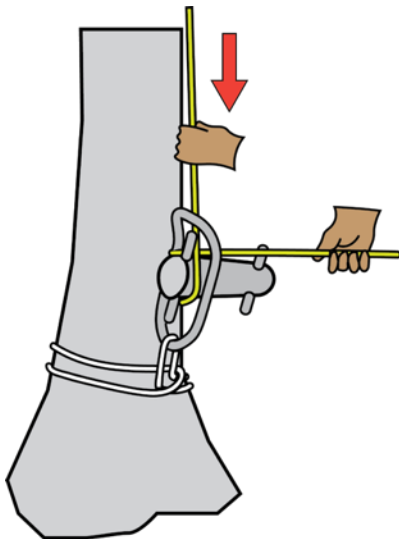


Using rope brakes: adding tension

Many different rope brakes exist, and it is beyond the scope of this MIS to detail the particular use of each kind. Some common principles exist however, which can be applied when using almost any rope brake.

Many rigging systems require **pre-tension** to be added to a line. This should be considered separately from the use of mechanical advantage systems to lift a suspended load – pre-tension is tension applied before the cut is made and the load separated from the tree.

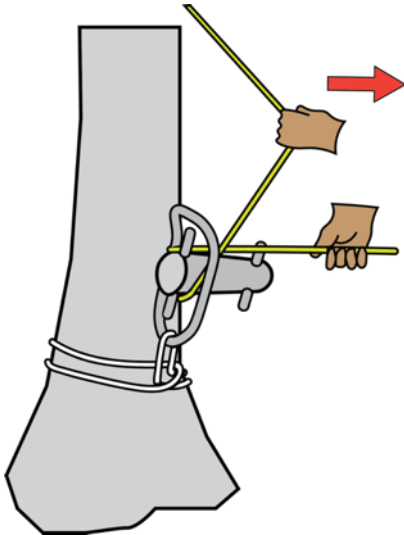
While some devices have components incorporated that allow additional tension to be added, most pre-tension is added by hand by one or more ground crew members.



1: Tension rigging line by hand and install into rope brake

Take up as much slack as possible before installing the rope into the rope brake.

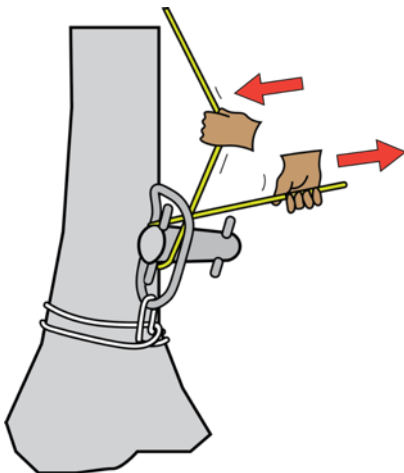
Install just one wrap – sufficient friction to allow tension to be held by hand but not so much that additional slack cannot be captured.



2: While holding the fall side of the line with one hand, deflect the rope away from the trunk above the rope brake with the other

Avoid pulling so hard that the rope is pulled through the device.

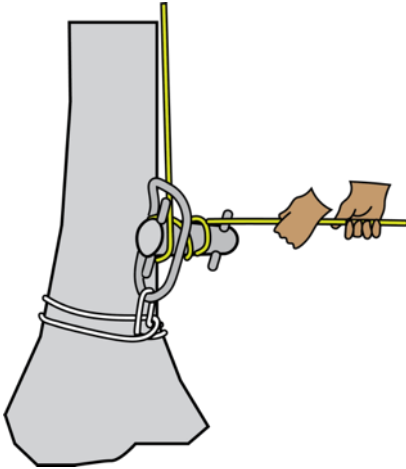
Using deflection force in this manner will allow much more tension to be put into the line than the limit imposed by the operator's weight if pulling down.



3: Decrease the amount of deflection above the device, while taking in slack through the rope brake

Practice will make this technique easy and effective.

Reducing deflection while simultaneously capturing slack will maintain the tension in the rope above the rope brake.



4: Install any additional wraps required and prepare for rigging operations

Practice will make this technique easy and effective.

Reducing deflection while simultaneously capturing slack will maintain the tension in the rope above the rope brake.

Rope control during rigging operations – general principles

Controlling the behaviour of cut pieces during rigging operations requires a complex interplay between load size, anchor point location, attachment point to piece, cut angles and piece weighting, and control of the rigging rope. The rope operator must have a clear understanding of the intended operation and know when to hold tension in the line and when to allow the piece to be lowered. Some principles to remember when managing a rope during rigging operations include:

Try to remove as much slack as possible before the back cut is made – slack in the rigging line will allow the load to drop further before the rope can bring it under control, which means more momentum to control.

Try to apply the **right amount of friction**. Smooth deceleration will be impossible with too many wraps; whereas no deceleration will be possible at all with too few.

Stand near to the rope brake if safe to do so. Slack between the operator and the brake will translate into increased force being applied to the rope and will prevent the smooth running of the rope brake.

Ensure that the rigging line is **flaked out correctly**, without loops, kinks or knots which may catch on obstacles, entangle you or become stuck in the device.

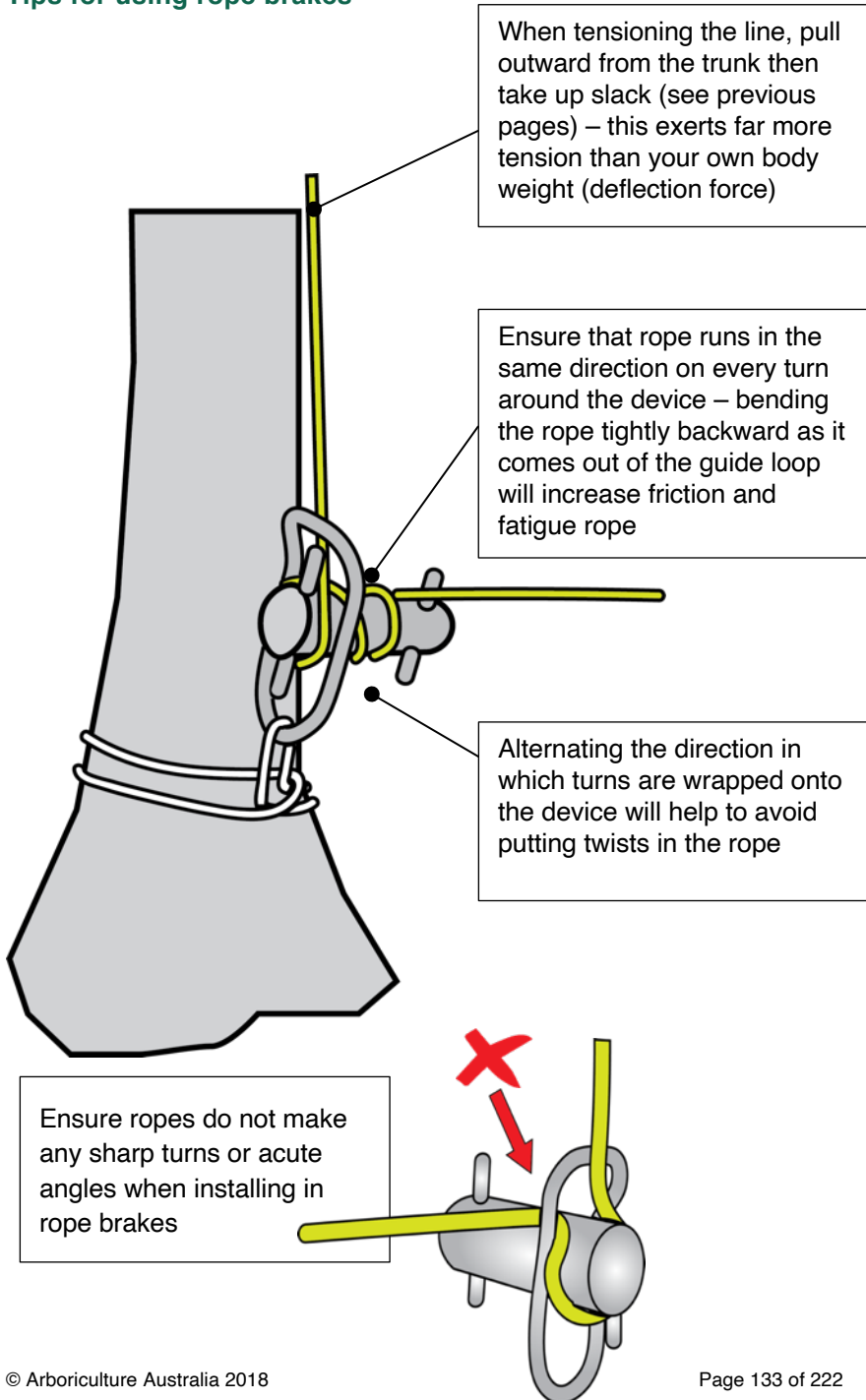
Ensure that you have **sufficient length of rope** to bring the piece to the ground.

Wear thick leather gloves or similar appropriate rigger's gloves. You will not be able to let the rope run through your hands with the correct tension if you are not wearing gloves.

Watch all components of the rigging system carefully as the load is lowered – ensure that nothing is running over the operator in the tree or interfering with access equipment or climbing lines. You may be able to notice things that the aerial worker has missed – stay in constant communication

Understand the rigging operation that is intended and work with the aerial rigger to achieve it. In many circumstances, loads can be controlled into the ground without ever being brought to a stop.

Tips for using rope brakes



Returning rigging components

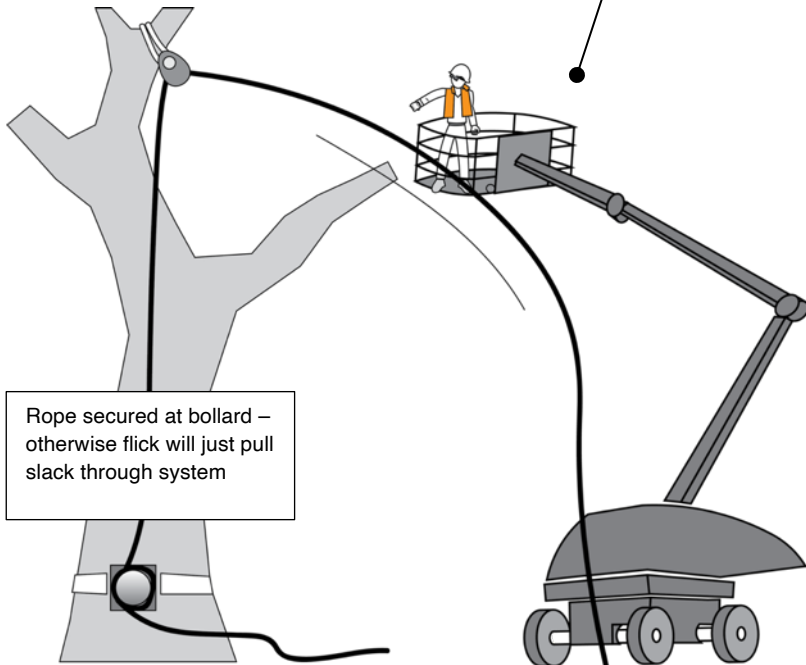
The difficulty in returning rigging components to the aerial worker will depend on the rigging system used, on the distance of the worker from the primary anchor point, and on how many obstacles there are between the aerial worker and the anchor point.

There are many techniques to make this process easier, such as:

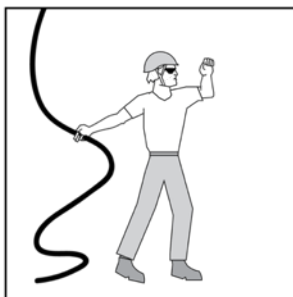
- Using a tagline or secondary rigging line.
- Using a return line.
- Using running anchor rigging.
- Attaching the rigging line to the tail of a climbing line and sliding it up the line to the climber by pulling on the tail of the rigging line.

In simple rigging systems, the fastest way is often for the ground crew to ‘flick’ the rigging line back to the aerial worker. Where the aerial worker is below or near the anchor point, this is not difficult – the challenge lies when aerial workers are level with the anchor point or a long way away! With practice, the rigging line can be returned by ‘flicking’, even from a long distance away.

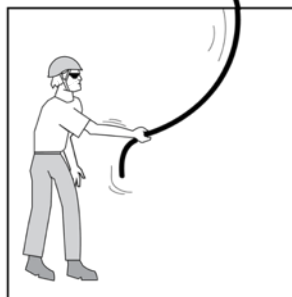
Try to stand in line with the aerial worker,
past them if possible, to bring the rope as
close to their hands as possible before
flicking the rope to them



Rope secured at bollard –
otherwise flick will just pull
slack through system



Additional slack is left
below hand before flick



Slack is released as the
rope is 'bowled' or flicked
toward the aerial worker

Specific rigging techniques

Natural crotch rigging

Natural crotch rigging is the technique of using the tree's natural features – unions, crotches, branches and stubs – as anchor points for rigging operations. Although in many cases there will be a high amount of friction when compared to low-friction blocks and pulleys, the practice of natural crotch rigging should not be mistaken for deliberately applying additional friction at the point of cut.

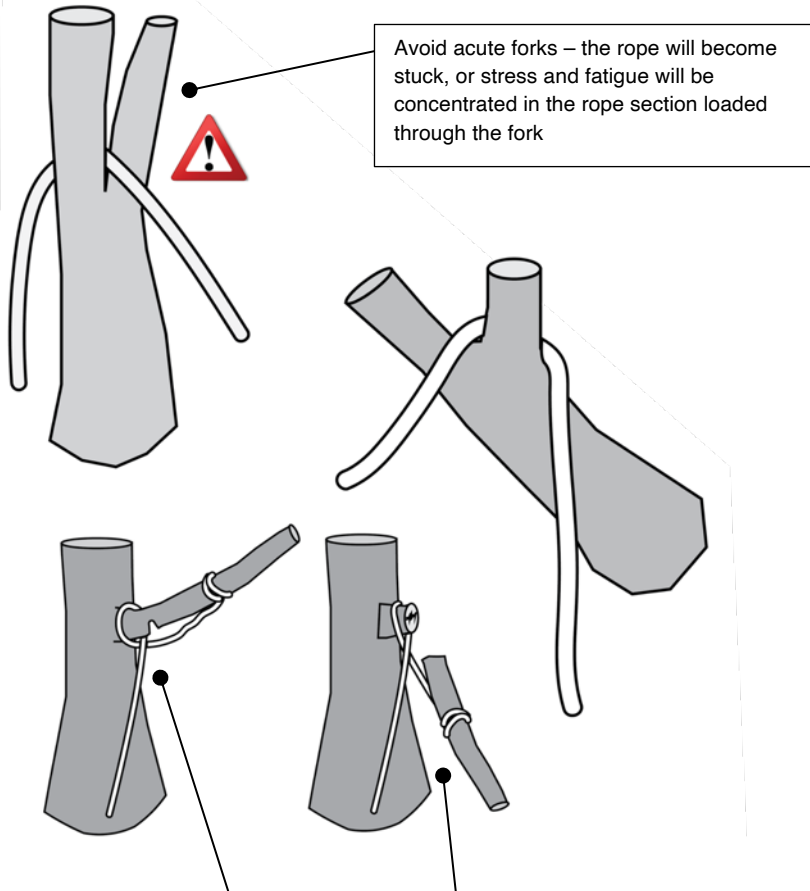
Throughout most of this MIS the practice of natural crotch rigging and the use of artificial moving rope anchors are assumed to be interchangeable, although of course each has advantages and disadvantages in particular situations. Tree workers are advised to attain proficiency with both techniques.

Natural crotch rigging has **advantages** including:

- Quick and easy to install rigging points, which can be installed remotely by throwing rope or string line through a target union.
- Allows branches to be rigged off during ascent, improving workflow.
- Residual friction may reduce force magnitudes at anchor point (depending on system and application).
- May negate the need for a rope brake due to friction at the anchor point.

Natural crotch rigging also has **disadvantages** including:

- Increased fatigue and abrasion on ropes; damage to tree cambium.
- Residual friction may make lifting more difficult.
- Requires suitable union or feature in correct place – do not use with acute forks.
- If rope 'binds' or crosses over itself, workers must be extremely careful not to get their fingers caught while untangling!
- It may be harder to estimate the number of wraps required at ground-based rope brake due to inconsistent friction between cuts.



Note that this rope installation may resemble 'friction at the point of cut', but once the piece is cut there will be just a single pass of rope over the stub and no full turns
Only a comparatively small amount of residual friction will remain

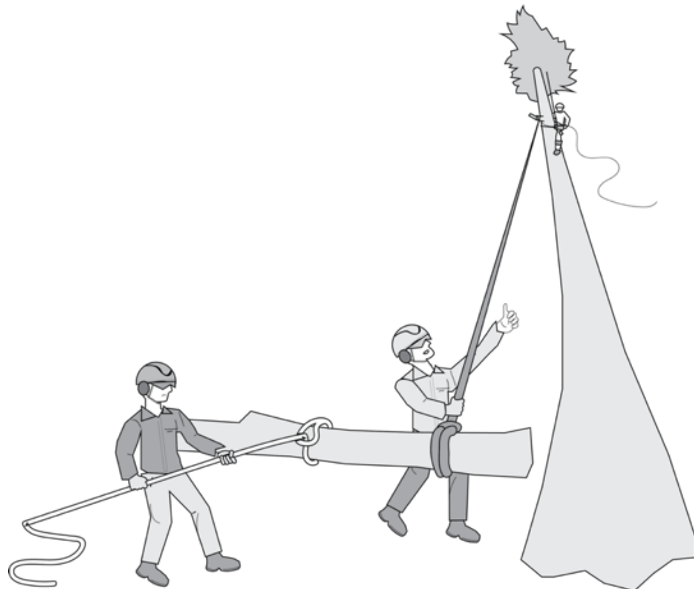
Applying friction at the point of cut

Any moving rope anchor point will apply some friction, depending on its efficiency. With natural crotch rigging this can be difficult to estimate, and many of the examples and equipment discussed so far do include large amounts of friction applied to the rope at anchor points within the crown.

It is also possible to deliberately apply friction at a rope brake within the crown of the tree. This approach has many advantages (see below) but also many disadvantages – in particular, the impossibility of lifting/freeing stuck branches, the physical difficulty of returning the line to the aerial worker and the difficulty of repositioning the line for each cut.

At the time of writing, some products exist that apply a small, fixed amount of friction during rigging operations but still allow for the return of the line (rigging wrench, SafeBloc, OxBlock, other thimble systems – see page 43, Rope brakes) and it is expected that further development will take place in this area. None of these devices provide sufficient friction to control any larger cut pieces.

One approach that addresses this is to apply the friction 'at the point of cut', which the aerial worker will access anyway to perform the operation.



This approach has many significant advantages, including:

- **Workflow:** as the climber/EWP operator can assist to control the rope, can lower the piece to the ground (assuming good line of sight/communication with ground crew), can return the rope (made easier if shorter ropes are used and rope ends are used alternately) and can reposition the rope for the next cut while ground crew process the previous piece (there is no need to 'flick the rope' back to the aerial worker). In addition branches can be removed during ascent – very useful on tall straight trees!
- **Simplicity** and speed of installation (depending on technique used).
- Reduction in **magnitude of force** applied to anchor point (See **Appendix B: Working the angles**).

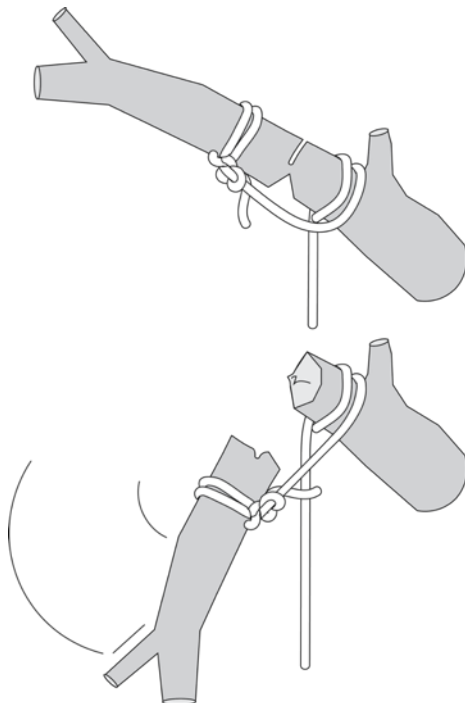
Applying friction at the point of cut also has disadvantages, including:

- Trunk wrap options will **damage many rope constructions** and will also **cut into the cambium**. This should not be used where tree parts are to be retained.
- Trunk wrap options rely on an interplay of piece size, rope diameter, bark friction, rope construction and rope control – this may be harder to predict and more challenging to apply accurately than the use of artificial rope brakes and anchors.
- Friction at the point of cut will inhibit any lifting operations and may make 'unsticking' any pieces that become hung up during rigging operations a very difficult problem.
- Using artificial rope brakes at the point of cut is comparatively slow and the range of friction may not be large. The artificial aerial rope brakes currently available are either cumbersome or very limited in the range of friction that can be applied.
- Reducing the rope in the system by applying friction at the point of cut **may increase shock loads and lateral forces** and will concentrate fatigue in the last few metres of the working end of the rope, which should be regularly shortened.

Techniques for applying friction at the point of cut

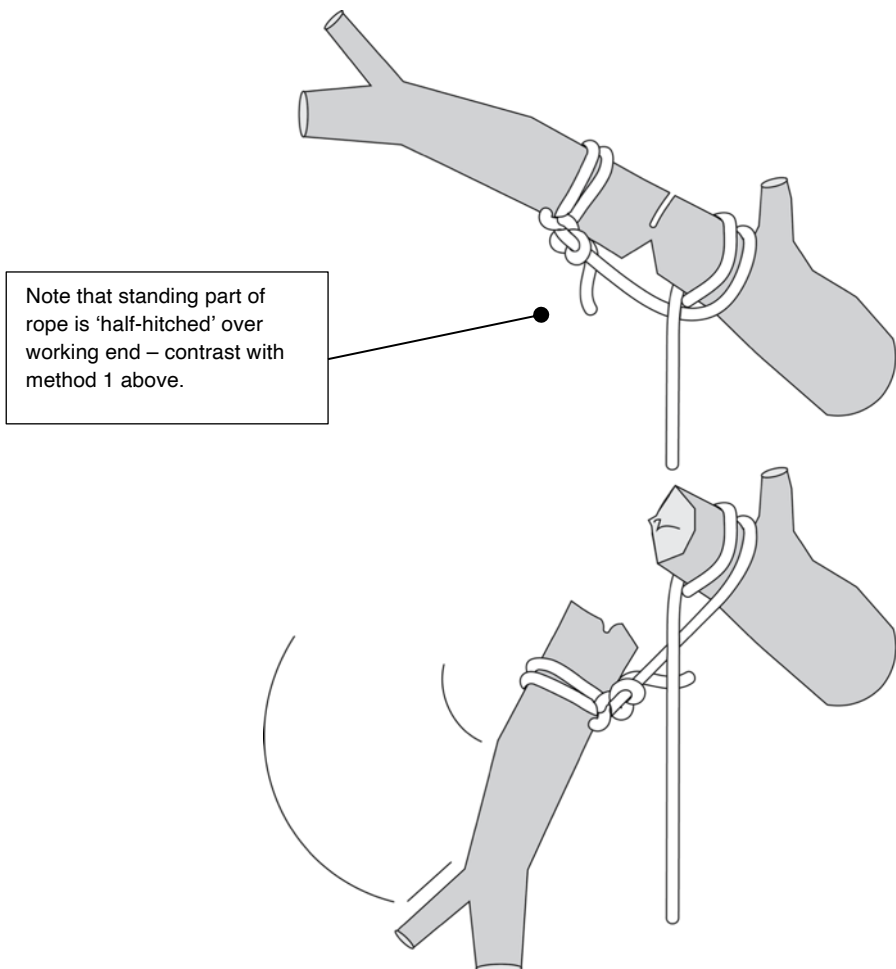
Branch removal – wraps method 1

- Ensure that wraps are made so that the side of the rope that will be holding the cut piece is lowest into the union – crossing the ropes will bind the working end across the standing part of the line – this may not be easily fixed!
- Ensure that the crew member controlling the rope does not pull in tension as the back cut is applied – rope can be ‘unwrapped’ from stub.
- Will not work with less than one complete wrap (as shown) as the rope weight will ‘unwrap’ itself from the anchor.
- Use one to three wraps depending on piece size.
- Easy for the aerial worker to ‘unwrap’ once piece being lowered.
- Ropes may cross over as there is no fairlead – climber must untangle. Ensure fingers are kept clear of ropes!



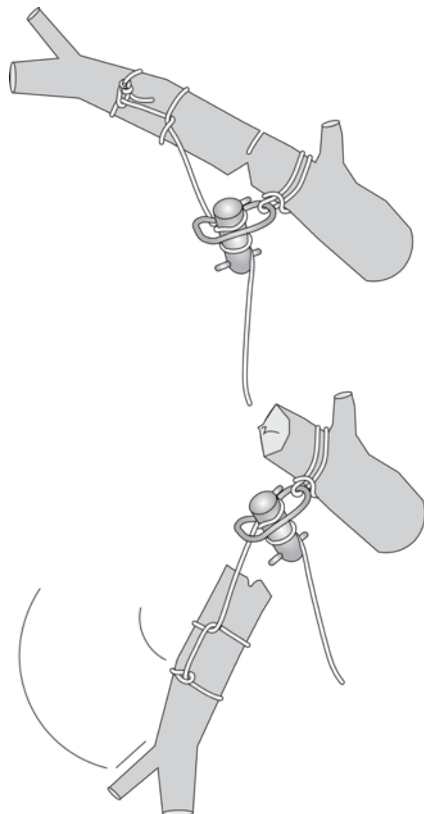
Branch removal – wraps method 2

- Ensure that wraps are made so the side of the rope that will be holding the cut piece is lowest into the union – crossing the ropes will bind the working end across the standing part of the line – this may not be easily fixed!
- Will work with less than one complete wrap – half-hitch will prevent unwrapping. In this instance, ensure that it is understood that no significant friction has been applied.
- Use zero to three wraps depending on piece size.
- Easy for the aerial worker to ‘unwrap’ once piece is being lowered.



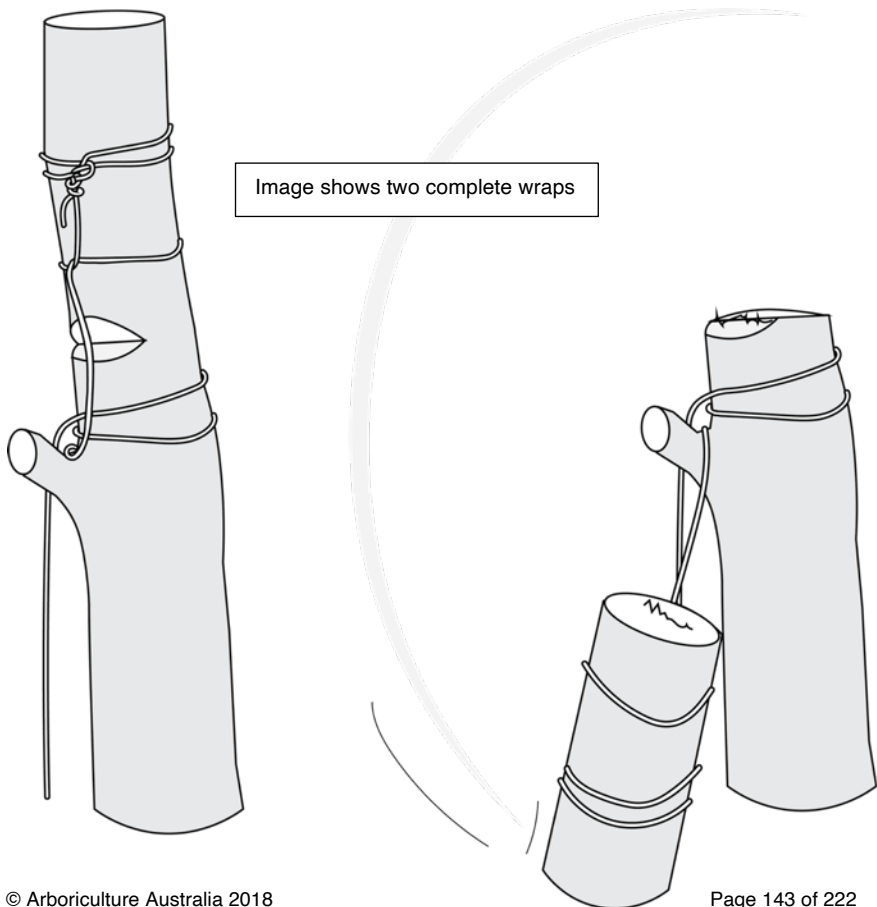
Artificial rope brake at point of cut

- Can be used for branch and stem/timber rigging operations.
- Use same technique for snatching (according to the recommendations for the device).
- At time of writing, no artificial rope brakes exist that allow a full range of friction to be applied and are still light and easy to relocate.
- Use of a Portawrap or similar is functional but slow to install and relocate.
- The addition of an artificial rope brake such as a Portawrap will lower the effective height of the anchor point compared to the use of branch wraps, increasing distance of free-fall and shock loads.
- Will not damage ropes or cambium.
- Wraps can be removed if necessary during rigging (depending on device).



Snatching – wraps at point of cut

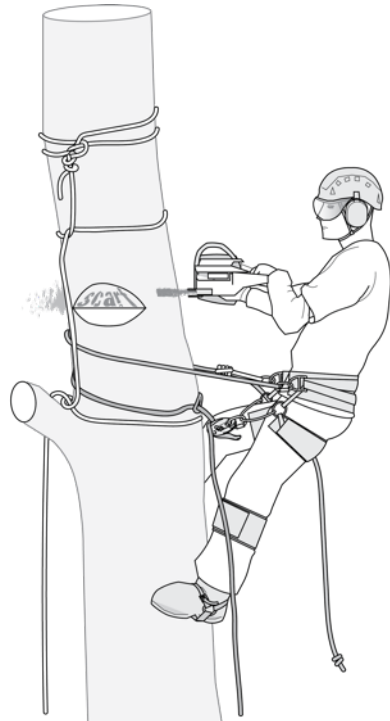
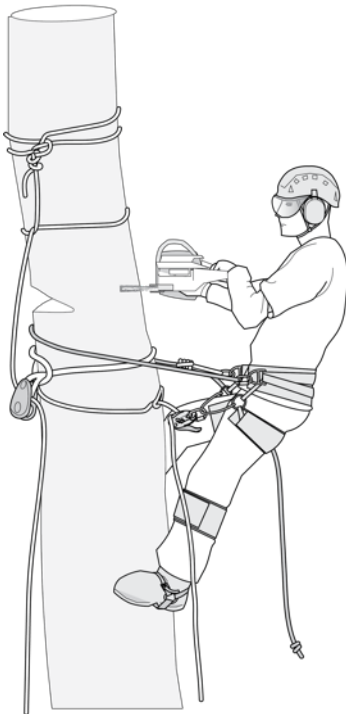
- Ensure that wraps are made so the side of the rope that will be holding the cut piece is lowest into the union – binding the working end across the standing part of the line will make it impossible to lower the piece.
- Use one to three wraps depending on piece size.
- Easy for the aerial worker to 'unwrap' once piece is being lowered.
- Harder to decelerate smoothly, when compared to a ground-based rope brake and rigging block.
- May be harder to keep climbing rope and lanyard away from running rigging lines when compared to the use of a rigging block and ground-based rope brake.



Snatching

Snatching is the technique of 'dropping' pieces into an anchor point below the cut. It can be performed with an artificial anchor (lowering block, pulley, rigging ring or similar device) or by using natural crotch rigging.

In the two images below, the climber is making a back cut prior to snatching the timber above him. In the left-hand image, an artificial moving rope anchor point (rigging block) has been used. In the right-hand image, the piece is to be rigged using natural crotch rigging techniques, with some of the friction taken at the point of cut (a single complete wrap).

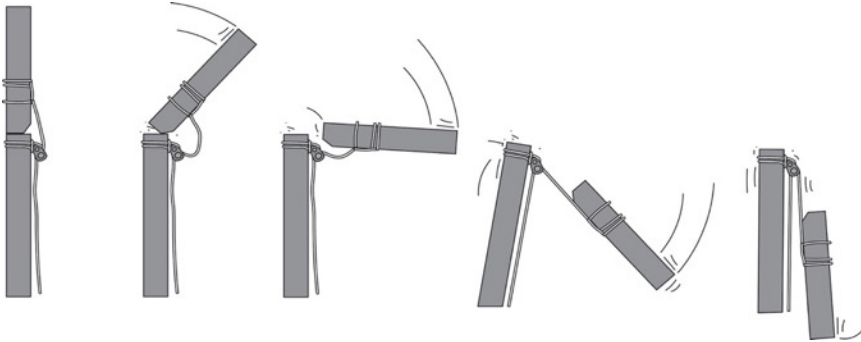


The concepts below are common to both techniques:

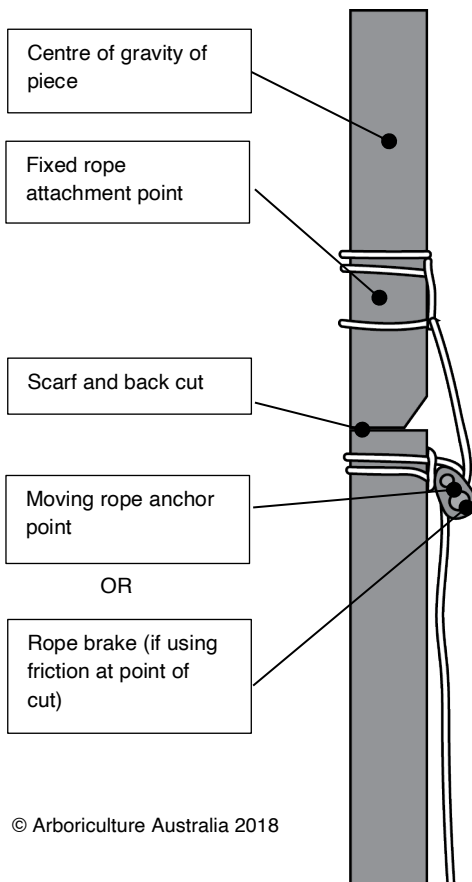
- The chainsaw should never be used above chest height. This helps to ensure ergonomic use, protection from kickback, operator safety and accurate cuts.
- Climbers must have two points of attachment whenever using a chainsaw in the tree². In the images on the previous page, the climber's main line is choked onto the trunk and configured so that immediate egress/evacuation is possible if required. Caution should also be used that rigged pieces do not come into contact with the line below.
- The two points of attachment and the climbing line can be arranged in any order that allows the chainsaw to be used, will protect against falling, and will avoid contact between the rigging rope or anchor point hardware and the life support lines:

Attachment	Attachment	Rigging anchor
Attachment	Rigging anchor	Attachment
Rigging anchor	Attachment	Attachment

- Selection between the above arrangements should include the following considerations:
 - Risk of rigging point slipping down the stem and trapping lines/injuring climber.
 - Maintaining sufficient line separation – two points of attachment must be separated to avoid cutting through both at once.
 - Avoiding both points of attachment being sited too close to the cut.
 - Avoiding the rigging line running across life support attachments.
 - Keeping the rigging anchor as high as possible to minimise distance of free-fall (see next page).
 - Allowing wraps to be 'taken off' if necessary (for friction at point of cut only).



The above image shows the process of snatching, assuming that the rigging line was tied off at the base of the tree – in most circumstances good rope control will reduce the shock force generated in this process! The following pages discuss each step of the sequence above, and provide some assistance with basic negative rigging ideas.



System installation

Distance between anchor point and cut will be doubled as distance of free-fall – try to place anchor point as high below cut as safely possible.

Distance from cut to rope attachment is not doubled – uncontrolled free-fall distance will be the same whether it is tied close to butt or tied high, providing the attachment is below the centre of gravity of the piece.

Ensure that attachment point is below centre of gravity of piece.

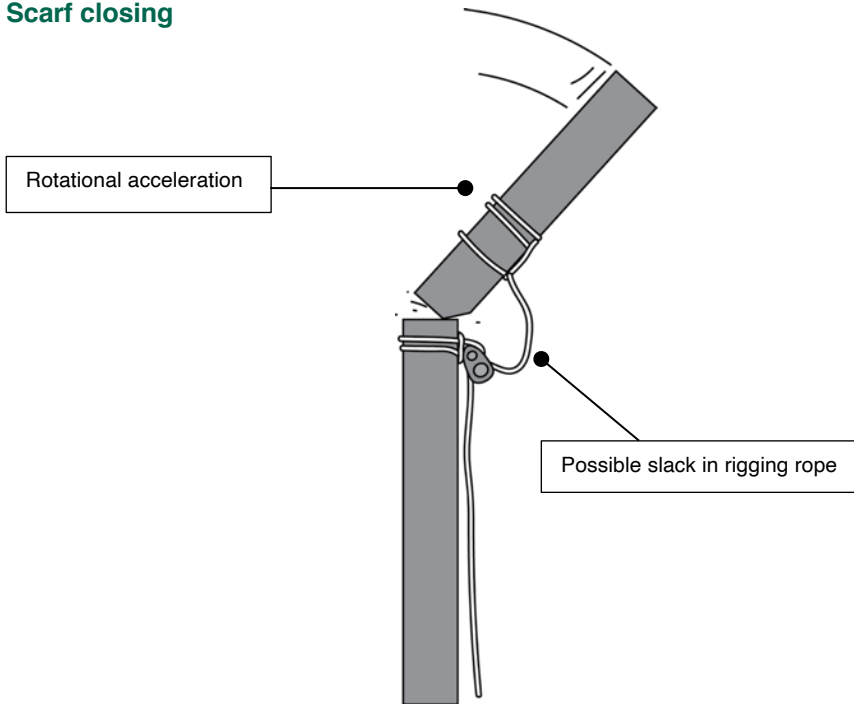
On short, slippery blocks the rope may need to be 'cut in' or additional side cuts used to prevent slipping.

Cutting scarf over 50% of way through diameter of vertical stem will place centre of gravity on correct side of hinge.

A more open scarf may assist in controlling rotation of section for longer, limiting shock load (species dependent).

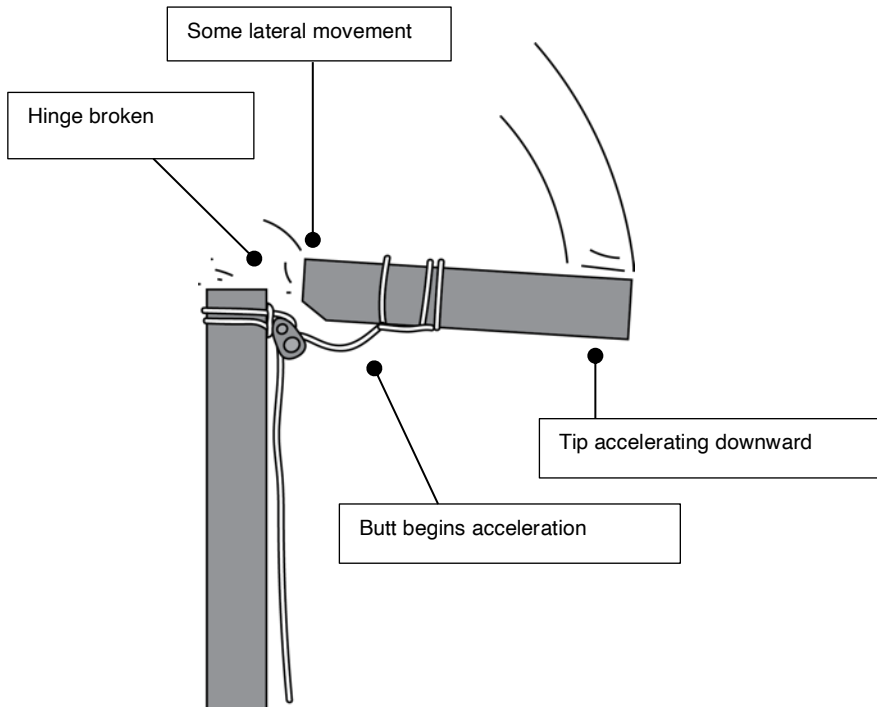
Ensure as much slack as possible is removed from line before beginning back cut.

Scarf closing



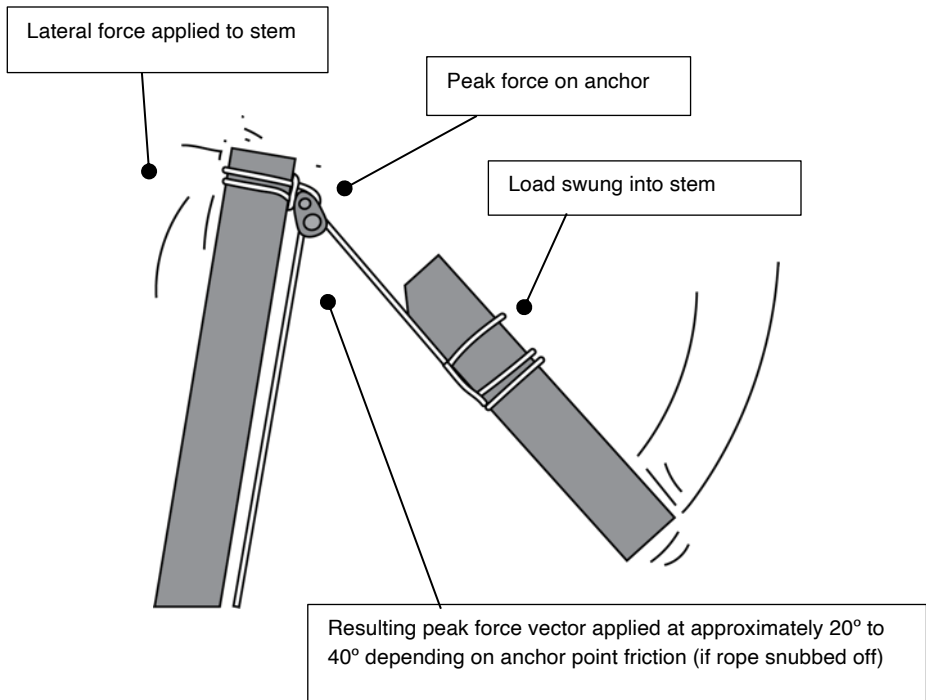
- Initial rotational acceleration will be slow as scarf closes.
- Rigging line may go slack (depending on tension and elasticity).
- Being able to take in slack during this part of the operation can limit shock load.
- An open scarf may control section longer and reduce shock load (in some species).
- At this point, significant backwards force is being placed on the upright stem. Ensure that back cut is made with a suitable step and be prepared for the stem to be pushed backwards.
- Different scarf cuts (Humboldt, Open Face) will affect lateral movement in some species and may affect rotation³. According to Detter (2008) a Humboldt scarf results in more horizontal displacement and a greater distance of free-fall.

Free-fall



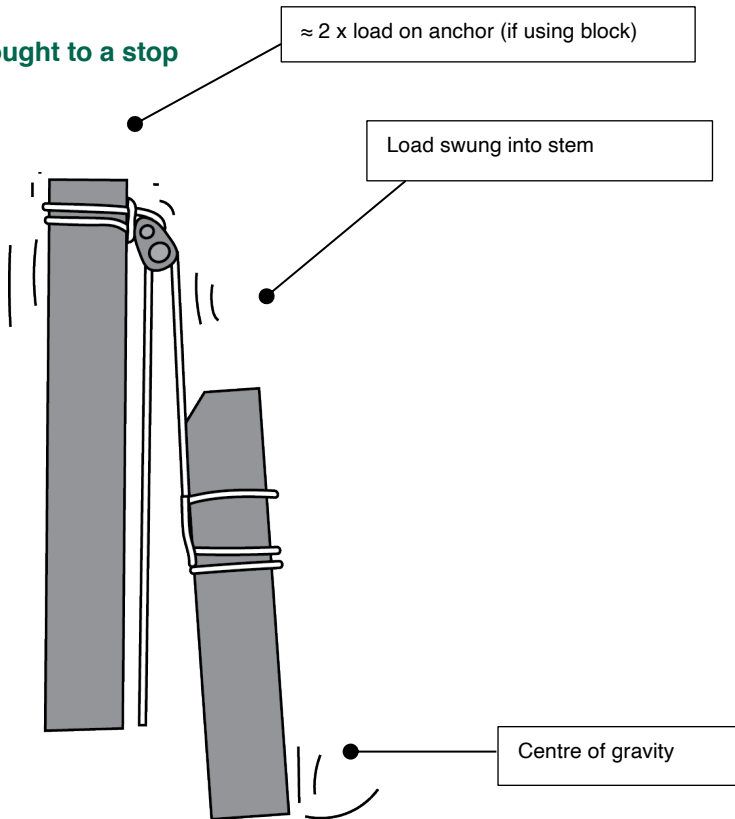
- If pre-tension/elasticity in rigging line is sufficient, rigging line may inhibit lateral movement.
- Rigging line may be slack (depending on tension and elasticity).
- Being able to take in slack during this part of the operation can limit shock load.
- Both butt and tip will now be accelerated downwards by gravity.
- Distance of free-fall is, at a minimum, twice the distance from the central axis of the anchor point to the bottom cut of the scarf.
- Note that kinetic energy is generated over a much greater distance than this – see next page.

Rigging system engaged



- The rigging system will come fully into tension when the load has fallen the same distance that it was above the anchor.
- At this point, the behaviour of the load will depend on the management of the rope by the controller. In an ideal situation, the load would be decelerated as slowly as possible over as long a distance as possible, or allowed to maintain a proportion of its momentum until it is stopped by the ground.
- Assuming that the rope is snubbed off, peak load usually occurs when the section is caught by the rope and swings back into the trunk.
- This is usually around 35° to 40° out from the trunk – the resulting force magnitude and direction (vector) will depend on the amount of friction in the top anchor and on the elasticity of the rope.
- Higher friction at the top anchor may result in lower force magnitude (no mechanical advantage) but worse force vector (more lateral movement).

Load brought to a stop



- If the rope is snubbed off or too much friction is applied, the load will be swung back into the trunk.
- At this point most of the deceleration has occurred – the main component of velocity for the load will be back into the trunk.
- Take care to avoid placing spurs and feet into this area – even if you are confident in the person controlling the rope, things can become bound or stuck.
- Note that the centre of gravity of the rigged section is well below the cut. Compare this to the height of the centre of gravity above the cut in the first image. Long sections will generate significantly more force than short sections, even of a similar mass!
- Impact of piece with stem may generate significant force – climbers should attempt to brace themselves using both hands and pushing on the trunk.

Minimising peak force in negative rigging

Working with experienced ground crew who reliably bring snatched sections to a halt in a smooth and gentle manner can lull climbers into a false sense of security and increase load size to the point where any mistake will result in failure of equipment or stems.

According to Donzelli and Lilly (2001)⁶, forces can be minimised by:

- **Cutting smaller pieces.**
- Using a rope with more stretch.
- Putting more rope in the system.
- Reducing the distance of fall.
- Letting the piece run and slowing it gradually.

The UK HSE *evaluation of current rigging and dismantling practices used in arboriculture* adds the following recommendations³:

- Retain branches and co-dominant leaders on the stem for as long as possible (see mass damping, next section).
- Use shock absorbers that do not significantly lengthen the rope.
- Tension the lowering line, as the line is slack during the log's free-fall.
- Avoid sling slippage at the anchor point.
- Leave side branches on sections to increase air resistance and cushion impact on the trunk.

In addition, tree workers could consider:

- Incorporating additional anchor points or moving existing anchor points or rope brakes to reduce lateral components of resulting forces (see **Appendix b: working the angles**).

Estimating peak loads in negative rigging

Various rules of thumb have been suggested to estimate peak loads during negative rigging. The following is proposed as the simplest to apply in practice:

*A study guide of Münchner Baumkletterschule (a German arborist school) advises applying a linear safety factor to rigging operations. The authors recommend that a **force magnification factor of 5** should be applied, in addition to the standard design factor for ropes (usually 5:1, i.e. a working load limit 20% of tensile strength) and an assumed strength reduction for rope of 50% due to knots. The factor of 5 was proposed to take into account the building up of peak forces during a lowering operation.*

HSE Evaluation of Current Rigging and Dismantling Practices Used in Arboriculture³

In other words, even when things go well, **estimate the weight of the section and then multiply that by five to arrive at an approximation of the peak load.**

Taking it further – forces in negative rigging with friction at the point of cut

The effects of deliberately incorporating a majority of the friction at the point of cut have not been well studied. The HSE tests showed that while the magnitude of peak force was reduced due to the removal of mechanical advantage at the anchor point, the reduction in magnitude was offset by an increase in the lateral component.³

In other words, the peak force will be reduced but the top will actually be pulled sideways more and there will be an increase in oscillation/tendency for stem failure.

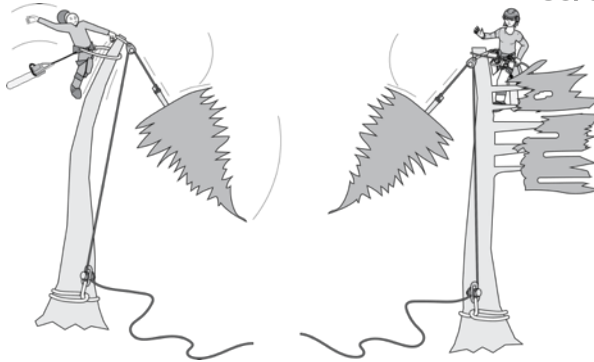
These results may be because the tests were conducted with the ropes 'snubbed off' – in this instance, the increase in elastic elongation due to more rope being incorporated into the system using low-friction top anchor points would explain the higher lateral force. If the rope brake on the ground can be set behind the axis of the stem, it is clear that lateral force can be reduced by using low-friction anchor points and applying the friction at the ground. If the rope brake on the ground is in front of the axis stem then greater lateral force may be applied when compared to the use of friction at the point of cut.

Mass damping

Mass damping occurs whenever branches, timber and foliage assist in reducing the movement of the tree structure during dynamic loading.

The effect of mass damping can be experienced by adding a weight to the end of a stick and waving the stick from side to side. The effect of mass damping will make it hard to accelerate the stick in either direction. With the weight removed the bare stick will be easy to wave from side to side.





Mass damping occurs during tree dismantling whenever retained branches, timber and canopy material assist in reducing the movement of supporting tree structure during rigging operations.

In the image above, the same size piece has been rigged out of each tree. The tree on the right will experience considerably less oscillation/lateral movement because the same lateral force (provided by the rigged section) now has to accelerate considerably more mass.

- Use of mass damping can help to prevent 'riding the pole' as in the image on the left.
- Take care to avoid getting rigged sections hung up in lower branches.
- When rigging out a vertical stem that splits into multiple leaders, rig the largest parts first if possible, then progress through to finish with the smallest. This will allow the mass of the smaller stems to assist with damping the oscillation caused by the larger rigging operations.

Taking it further – mass damping

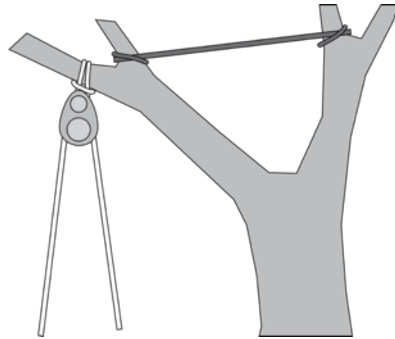
According to Newton's second law of motion:

$$\mathbf{F = m a, \text{ or } Force = mass \times acceleration.}$$

In this instance, the lateral force provided by the rigged piece is the same, but the greater mass of the tree on the right will mean that the same force provides less resulting acceleration. Trees are incredibly effective at **compound mass damping** – force applied to living trees is dissipated in the movement of stems, branches, twigs and leaves throughout the crown and canopy. This can be easily observed by watching the movement of a tree during dismantling operations.

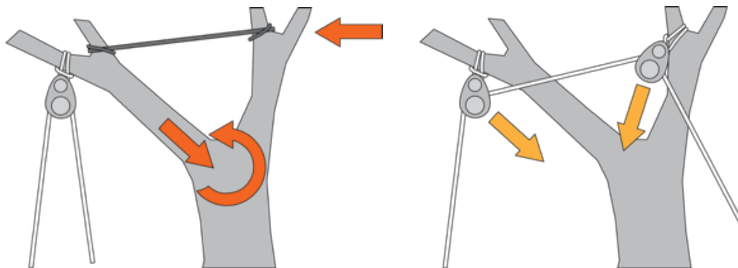
Bracing a rigging point

Bracing a rigging point is the technique of using additional slings or ropes to support a section of tree which will bear a load during rigging operations.



In the image above it has been decided that the day's work will run more smoothly with the anchor point set out on the left-hand branch rather than in the main union. An additional brace has been installed (using a short stop or length of rope) to support the branch during rigging operations. In more complex scenarios, multiple braces may be used, or longer braces used to support a whole tree during rigging operations (see page 166, Guying a tree).

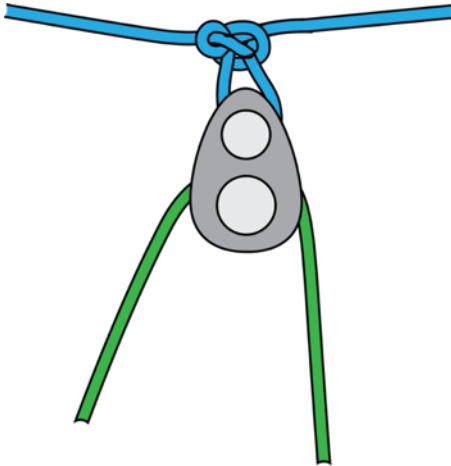
While this can be an effective technique, care must be taken that the impact of rigging operations on all components in the system are fully understood.



In the two images above, compare the lateral force applied at the bracing point and the compound bending at the union, with the smaller force vectors applied by the use of multiple anchor points.

The use of bracing can improve safety and efficiency on aerial rigging jobs but it should be used with care and with a full understanding of the forces applied to all components. Please see **Appendix B: Working the angles** for more details.

Floating anchors: highlines and multiple point floating anchors

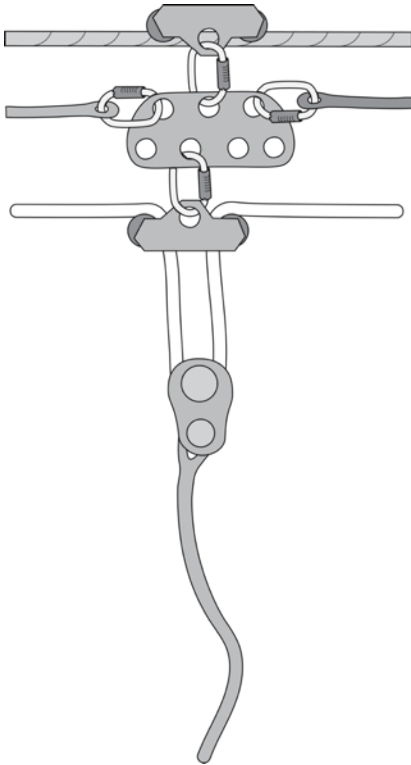


- Example of a simple floating anchor point system
- Lateral movement only possible by unloading and adjusting support line
- Support rope (blue) will be weakened by knot

Floating anchors are rigging points – usually arborist rigging blocks or pulleys – which are suspended in a particular place by the use of anchor lines. The use of floating anchors to position a rigging point can be a powerful technique, both for complex, technical trees and to improve efficiency on even simple jobs. Highlines are also often used to create anchor points for climbing lines (both MRT and SRT) and many of the same concepts apply for both applications.

1. Identify support trees, anchors or structures.

Two or more trees can be used, but if one tree is tall enough then the use of a single high point and a ground anchor may be sufficient to site the anchor point in a suitable location.



2. Design highline or similar floating anchor point system.

Remember that multiple support lines may be used.

Lines may be joined using appropriate knots or connectors.

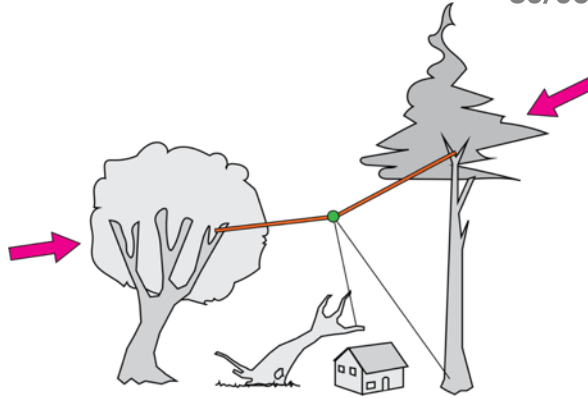
3. Identify forces which will be applied to all components of system.

Forces in highlines and applied by highlines to support structures may be very high. See **Appendix B: Working the angles** for more details. It is critical that the magnitude of these forces is understood before using these techniques!

- Example of a complex floating anchor point system
- Can be floated under load in either direction along the support line, and the white rope can be used to lift sections with a 2:1 mechanical advantage

4. Adjust system as necessary to reduce forces wherever weak points identified.

Many adjustments to floating anchor systems are possible, often simply by changing the angle of the support lines or lowering the anchor point (please see next page).

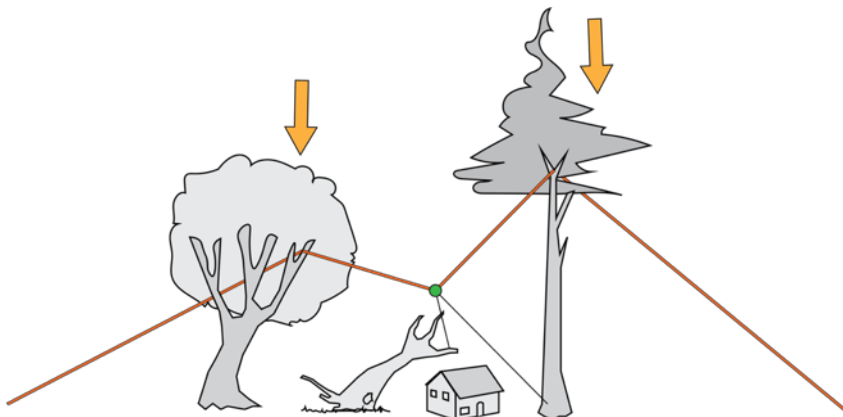


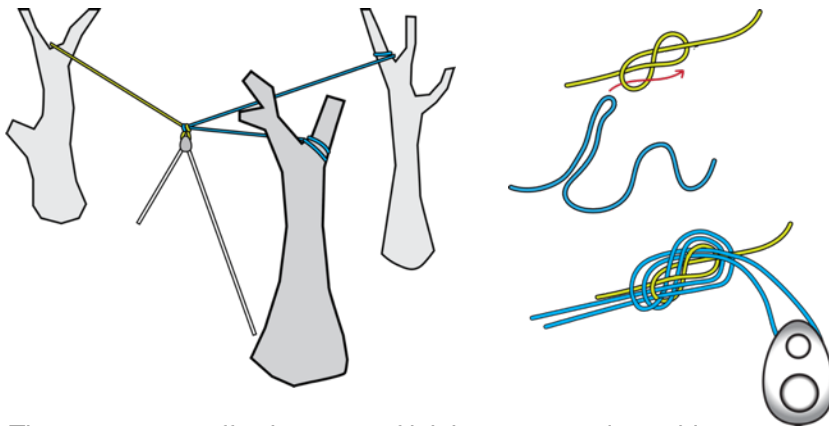
In the image above, an anchor point has been installed on a highline to begin work on the uprooted tree below. While the anchor point may be in the right position, the setup will generate a high magnitude of force at either attachment point. Even worse, the direction the force will be applied is almost perpendicular to the stem on each of the supporting trees. This is very likely to cause structural failure in one of the two support trees.

In the image below, the anchor point has been lowered to the lowest point possible to efficiently conduct the work and the highline has been secured to ground anchors away from the support trees. This will:

- Reduce the magnitude of force applied to each support tree.
- Improve the direction that the force is applied. Ideally, force should be applied as compression directly in line with the stem.

For more details on these concepts, please see **Appendix B: Working the angles**.





There are many effective ways of joining ropes and attaching hardware to achieve 'three-dimensional (3D) rigging' setups. The use of 3D rigging hubs or rigging plates should be considered wherever significant loads are anticipated.

The knot above (Retraced-8 on a bight, figure-8-bend on a bight, Flemish bend on a bight) is an effective way of joining three ropes to attach rigging hardware. Ensure that each arm of the midline-attached (blue) rope is sufficiently long to reach the supporting structure. The bight that emerges can be used to attach the block or other device.

Strength reduction will depend on the angle between the arms of the midline-attached knot and their comparative loading. As a rough guide, this knot should be treated as reducing the WLL of the ropes to approximately 50% of unknotted strength.

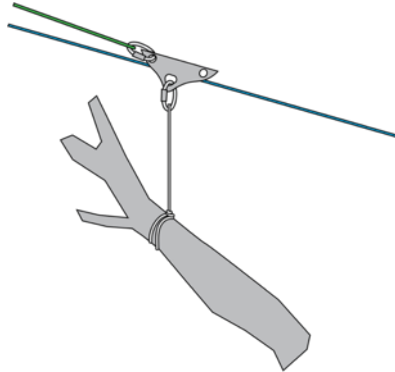
A similar knot can be used to join four ropes if necessary.

- When designing highline setups, setting the floating anchor as low as possible for the work to be conducted will minimise force in the support lines.
- The use of static rope for support lines will make the final position of the floating anchor easier to calculate and will require less pre-tension to be applied to the line. Static lines should be used with care, however, if static lines are used for highlines and are set 'taut' (or near level) before the floating anchor is loaded, very high peak forces can be generated.

Speed line or zip line

A speed line, also called a zip line, shares many of the same installation considerations as the use of a high line.

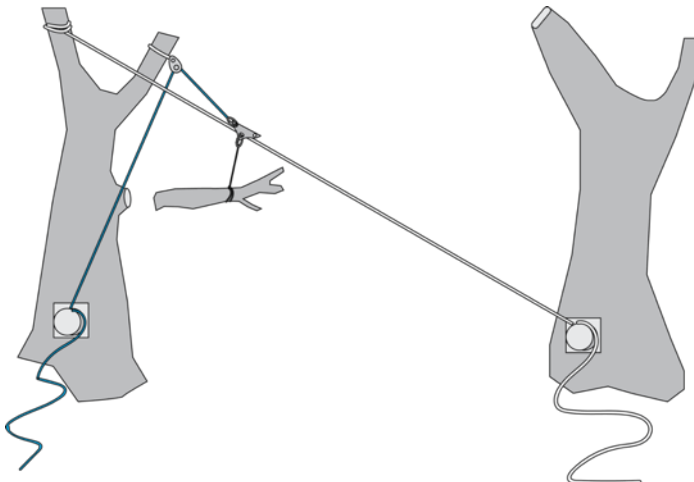
In both, a support line is held taut across a distance, and then deflection force is applied at the centre – great care must be taken that the anchor points at either end are sound and suitable for the forces that will be applied.



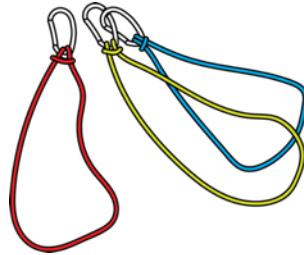
It will normally be necessary to adjust the tension in the main speed line – slack will need to be introduced to allow the aerial worker to attach the line to the part which is to be cut, before the line is re-tensioned.

Speed lines can be **controlled** or **uncontrolled** – this refers to whether the load is being lowered along the line (as in the pictures to the right and below) or is cut and allowed to slide freely down the line.

In **controlled speed line** operations, the load can be controlled by attaching an additional lowering line to the trolley or to the load. The load can then be controlled by the application of friction, either in the tree (controlled by the aerial worker) or on the ground (as in the image below). The lowering line will normally be used to return the trolley and rigging connectors back to the tree to repeat for the next operation.



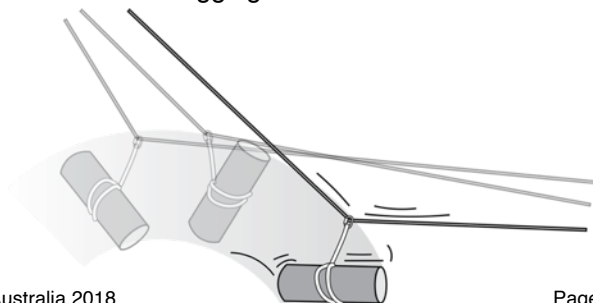
In **uncontrolled speed line** operations, the aerial worker usually carries several connections (multiple slings and snaps, for example) so that several loads can be sent down before needing to bring back all of the connectors.



The use of uncontrolled speed lines can be an effective solution to many rigging challenges. In particular, uncontrolled speed lines can be an excellent way of processing multiple smaller loads, such as de-limbing conifers or while conducting pruning operations.

Some important notes for uncontrolled speed line operations:

- Snap links (as pictured above) can open unexpectedly and should only be used where accidental opening is not a concern, for example, where speed line rigging is being conducted to ease processing of debris or because the site below is awkward to access, rather than where loads will pass above infrastructure or ground crew.
- High forces can be generated in uncontrolled speed line operations. In particular, 'bouncing' of loads on the line (as illustrated below) can generate very high forces and unexpected movement of the load.
- Bouncing can be exacerbated by stop-start, jerky movement of the load. This will be a frequent occurrence if heavy loads are secured using karabiners or snap-links (as shown) – use a suitable block at minimum and a tandem trolley style pulley at best whenever speed-lining heavy loads.
- Avoid shock loading any high line or speed line – the resulting forces at either attachment may be extreme! Please see page 69, Introduction to forces in rigging.



Running anchor rigging

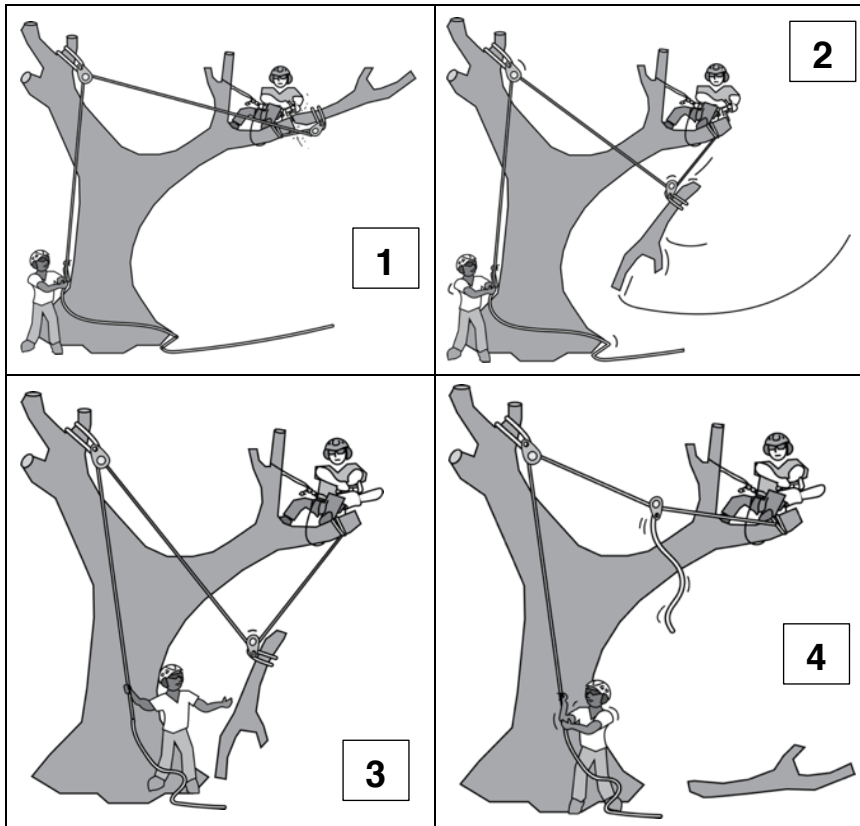
Running anchor rigging can offer a smooth and easy solution to what would otherwise be an extremely challenging rigging problem. Examples where running anchor rigging could be considered include:

- trees with no suitable anchor point over the lowering zone.
- lifting operations where a mechanical advantage can be achieved.
- trees where excessive swing of pieces toward the anchor point must be controlled or avoided.
- trees with extended limbs where returning the rigging line to the aerial worker will be time consuming.

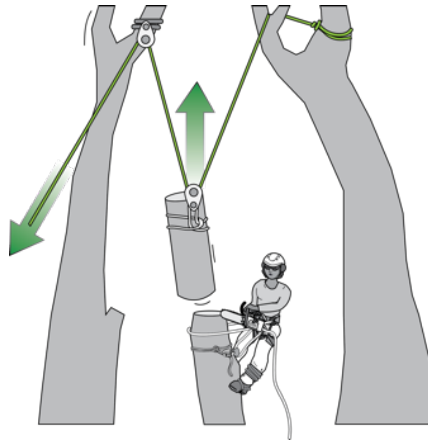
In all of these circumstances, running anchor rigging could offer an efficient and safe rigging solution. In addition

Before using running anchor rigging systems, ensure that the **large forces which can be generated using these techniques** are fully understood and that all components are suitable.

Running anchor rigging example



Note that the running anchor can be easily returned to the aerial worker simply by pulling on the tail of the rigging rope.



In the image above, the climber has chosen to use a running anchor rigging setup to enable log sections to be lifted vertically from the stump. This can be an easy and effective method for conducting lifting operations, particularly where (as in the image above) the anchor points are separated and a single anchor would not be directly overhead.

Forces during running anchor rigging should be worked out 'back to front' – while the angle between the two sides of the rigging line is acute at the running anchor the load is shared 50% on each side and there is a 2:1 mechanical advantage for lifting.

The higher the load is lifted toward the two upper anchors (one fixed, one moving rope), the less mechanical advantage is available and the greater the force that is applied to each anchor.

By the time that the running anchor approaches the height of the two anchor points:

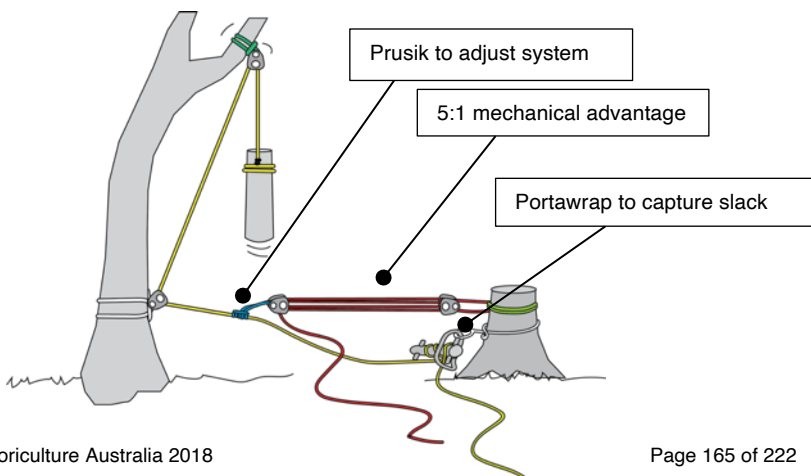
- It will be almost impossible to lift the load: for a 100 kg load, lifting the last 20 cm may require a ton or more of force, depending on the distance between the two anchor points.
- The force applied to the anchor point on each side may be as high as 500 kg or more.
- The direction of force will be almost the worst possible on each anchor point – applied laterally, almost perpendicular to the arm of the stem.

Lifting systems – mechanical advantage

Mechanical advantage is used in many applications in tree work: from influencing lean when felling trees, to conducting rescue, to pulling out bogged vehicles and applying tension to rigging lines.

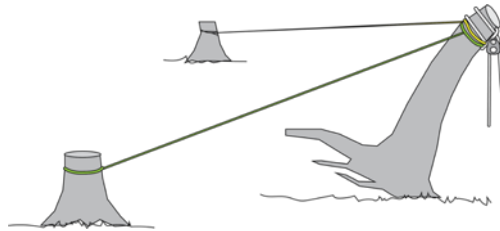
When used in rigging applications, considerations should be given to the following factors to ensure that the system is appropriate for its intended use:

- Actual **mechanical advantage** achieved – will it be sufficient for the lifting or tensioning required?
- **Speed** of the configured system – significant mechanical advantage step-ups may result in slow speeds of pull. While this may not be a factor for lifting pieces, it may be catastrophic while felling side-loaded trees.
- Ability to quick-release mechanical advantage system if necessary.
- Ability to capture slack as it is generated.
- Ability to slow-release, lower or adjust system under advantage.
- Where force will be applied – lifting operations where there is friction at anchor points may generate significant force.
- Remember that **deflection forces can be an effective way of generating force** – tensioning a rope and then deflecting it may out-perform even commercially made mechanical advantage systems.



Guying a tree

The use of tensioned **guy ropes** to support trees where the integrity of the stem or root system has been compromised can be



a powerful technique. A full discussion of the application of this technique is beyond the scope of this MIS: specific training or mentorship should be sought prior to use.

Considerations when guying for rigging work should include:

- The elasticity of the guying ropes and the amount of tension applied: when the weight is removed from the tree, the guy rope tension must not pull the remaining trunk back over against the original lean.
- The possibility of **impact of rigged pieces on the guying ropes** – massive deflection forces and catastrophic tree failure could result.
- The angle of attachment of the guy ropes to the failed tree – too acute an angle of attachment will either provide little support, or will require extremely large tension (and corresponding downward component of force) to provide the required support.
- The impact of the guy rope on the tree's natural flexibility and response to loading (of particular concern with extremely static guy ropes). Very little research has been conducted on the response of trees to guying during high-load rigging operations, but users should consider if they are introducing a weak point at the guy attachment point.

3: Completing tree removal

Please see **MIS315 Chainsaw Operations** for consideration of the following:

- Felling the stump.
- Crosscutting and processing the timber.

Please see **MIS300 Safe Tree Work** for discussion of the following:

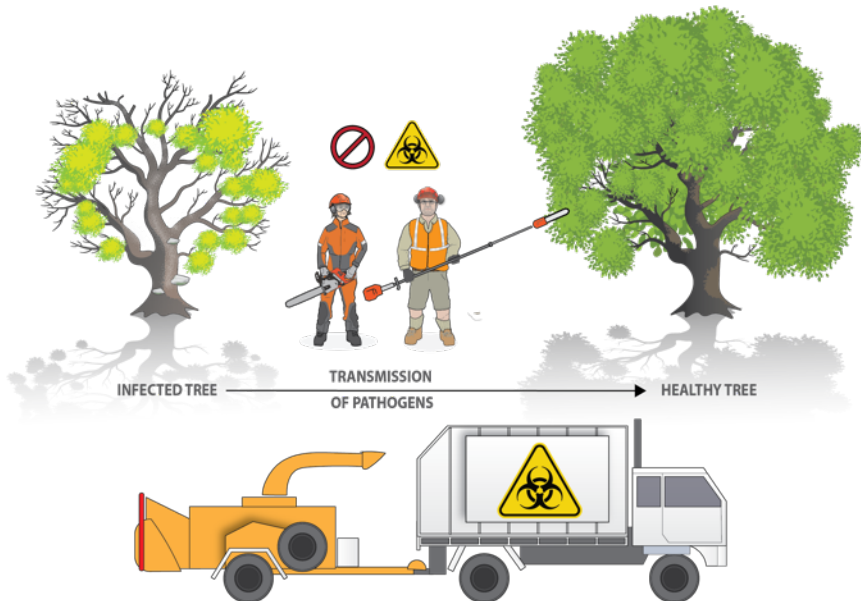
- Processing debris.
- Cleaning, storing and transporting equipment.
- Retiring condemned equipment.
- Reviewing completion of the scope of works.



Biosecurity and transmission of pathogens

Some diseases that harm trees can be spread through pruning tools or equipment, or the installation tools for structural support systems, or through the transportation of infested materials.

Biosecurity describes the measures and work practices designed to minimise the risk of introducing and spreading unwanted pests and diseases.



In areas where transmissible tree diseases are known, arborists must identify infected plants and follow optimal biosecurity measures to minimise the risk spread.

Poor biosecurity practices by arborists may contribute to the death of the very trees they have been employed to care for.

This may be of particular concern when dismantling infected trees, and then continuing to perform other tree work.

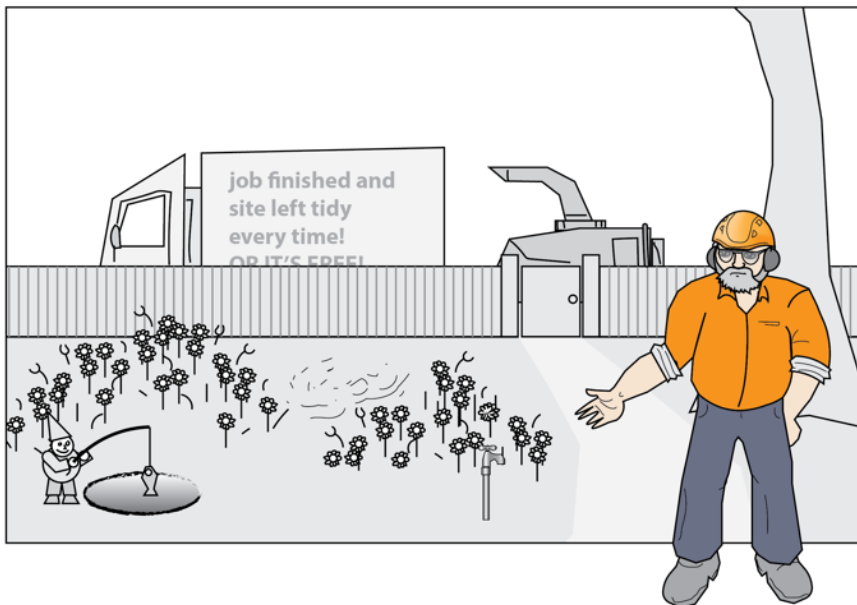
Biosecurity measures to maintain optimal hygiene and prevent spread are described in **MIS300 Safe Tree Work**.

Completion of works

Before leaving the site, if possible, arborists should confirm that the client is happy with the completed works, that the scope of works has been completed and that no damage needs to be repaired. If anything has been broken, the client should be informed as soon as possible, even if the damage has been repaired.

It is much better to have this conversation before leaving the site if possible – once you have driven away, something as simple as a garden bench you forgot to return to its original position may turn into a long drive back or an irritated client who may delay payment or give negative reviews.

Try to leave every job site just the way you found it – with all works completed as required and a happy client!



Appendix A: Rigging system diagrams

Key to diagrams and common system design considerations.

The rigging system diagrams on the following pages have been adapted from illustrations prepared by Mark Bridge for the *Evaluation of current rigging and dismantling practices used in arboriculture* (HSE UK 2008).

This is not intended to be a comprehensive list of possible rigging systems. In addition, components of many of the illustrated systems can be 'mixed-and-matched' to achieve desired outcomes.

Novice climbers should avoid systems with warning symbols until specific training in their use has been provided.

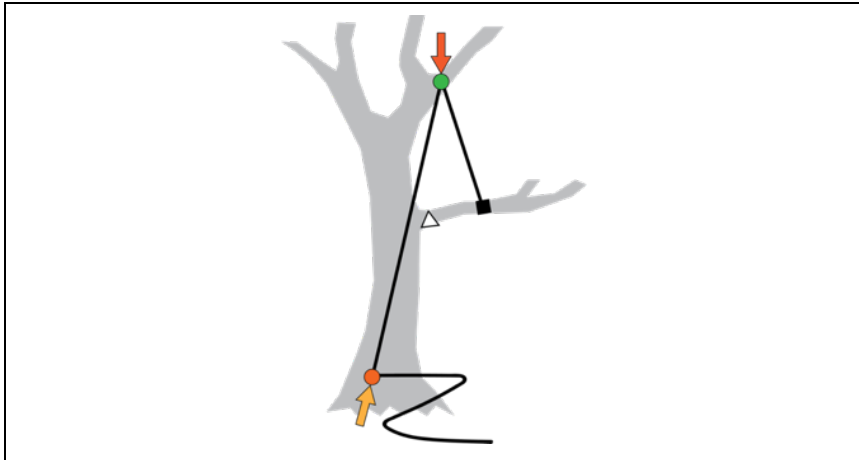
Symbol	Component	Elements	Common system design considerations
	Tree, tree part or anchor	Any tree part suitable for use in selected rigging operation Tree being rigged or adjacent tree Suitable natural or artificial anchor	Structural integrity of all tree parts during rigging operations, including roots, stem, branches and canopy Direction (vector) in which each part will be loaded Location of tree part Contact between tree part and climbing or access system at any point during rigging operations
	Rope	Any rope suitable for the rigging operation under consideration (see MIS302 Arborist Ropes)	Elasticity of rope WLL of rope Durability of rope Age of rope and history of use Compatibility with hardware/anchor points Contact between rope and any other system component, tree part or other infrastructure at any point during rigging operations Contact between rope and climbing or access system at any point during rigging operations

Symbol	Component	Elements	Common system design considerations
	Fixed rope anchor point	Suitable rigging knot or series of knots (see MIS302 Arborist Ropes) Other fixed connection, see page 27: Fixed rope anchor points	Loss of rope strength of connection choice Ease of attachment/detachment after rigging operations Age of rope and history of use Suitability for intended use – direction of loading, tendency to slip, behaviour under dynamic loads
	Force vectors Moving rope anchor point (no friction added)	Shown as a rough guide only in some diagrams, with magnitude increasing left to right Suitable tree crotch or union (see page 136: Natural crotch rigging) Suitable rigging block, pulley, rigging ring or similar (see page 33: Moving rope anchor points)	Force vector magnitude and direction Tree and system component strength and integrity under projected loads Strength and structural integrity of all anchor point components under intended load Direction (vector) in which it will be loaded Ease of attachment/detachment after rigging operations Suitability for intended use – direction of loading, damage to rope, behaviour under dynamic loads Location of anchor point – suitability for intended lowering operations
	Rope brake	Suitable tree part or union (see page 138: Applying friction at the point of cut) Suitable friction drum, bollard, winch block or similar (see page 43: Rope brakes) Suitable in-tree friction device (rigging wrench setup, SafeBloc, or similar)	Strength and structural integrity of all anchor point components under intended load Direction (vector) in which it will be loaded Suitability for intended use – direction of loading, ease of adjusting friction, behaviour under dynamic loads, ability to pre-tension

Symbol	Component	Elements	Common system design considerations
	Point of cut	Scarf and back-cut, step cut or other suitable cut for intended rigging operation Note: direction of triangle does not necessarily show intended angle of scarf	Direction, depth and angle of scarf or other cut to control tree part movement (see page 101: Cut sequences and techniques) Tree species and behaviour of tree Ability of worker to access tree to make required cut Vulnerability of worker making cut to subsequent rigging operation
	Join between two or more ropes	Suitable knot/s, rigging plate, ring or similar Avoid using a karabiner as this may result in cross-loading and a significant reduction in strength	Direction and magnitude of forces to be applied Loss of rope strength of attachment Whether the join will be moving or static – whether it will come into contact with other tree or system parts Ease of attachment/detachment after rigging operations
	Force applied to rope	Shown only in some diagrams where sustained lifting or pulling operations are being conducted	Impact of additional force applied on all other components in system Speed of force application Magnitude of force Ability to release quickly if necessary (after branch swing/felling or if rope comes into contact with other tree parts)

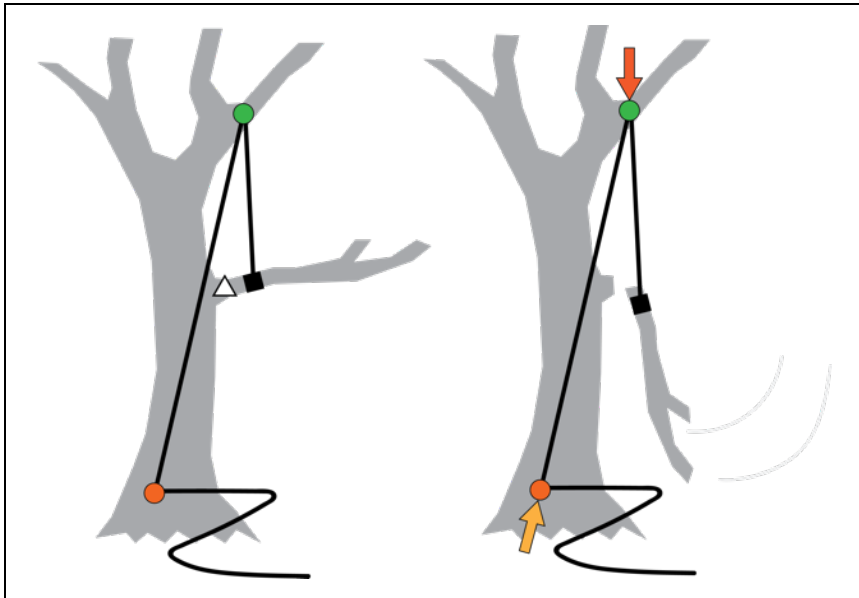
Positive rigging systems

Simple anchor I friction at base of tree



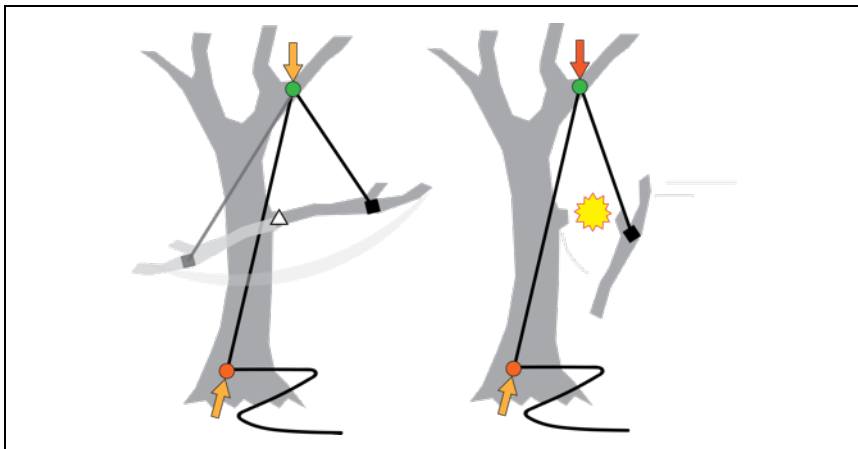
Element	Specific system design considerations
	Location of branch rope attachment – see page 178: Cradle rigging; page 174: Butt tying; page 175, Tip tying. Consider intended behaviour of branch following cut, impact on anchor point of dynamic movement, and manner in which piece will be lowered to the ground.
Additional notes	
Relationship between rope attachment point, location of anchor point, rope tension, cut choice and direction will determine behaviour of lowered tree part. Consider both immediate behaviour of lowered tree part (as it is cut, dynamic movement) and intended lowering operation – will it be easy for the ground crew to control and lower into the lowering zone on the ground? Tying closer to the butt (see page 174: Butt tying) will result in less rope control over the branch, more control by the hinge; some buildup of kinetic energy prior to rope control, may give protection to tree worker making cuts. Tying closer to the tip (see page 175: Tip tying) will result in more rope control over the branch, less control by the hinge; good ability to support or ‘swing’ the branch may put the tree worker making the cuts at risk.	

Butt tying



Element	Specific system design considerations
	Little control by rope means behaviour of cut piece will be strongly affected by cut choice and direction as well as branch shape and weight.
Additional notes	
Tying closer to the butt will result in less rope control over the cut piece until the hinge breaks and the branch weight is taken by the rope. Behaviour of cut piece until this point will be more strongly controlled by the hinge. Reduced ability of the rope to support the cut piece until the hinge is closed may result in a buildup of kinetic energy as the tip swings down, causing shock load. Because most of the weight will swing down below the point of cut, butt tying pieces like this can protect the worker making the cut if the system binds up or cannot be 'let run' – even a small amount of elongation in the rope will allow the cut piece to drop below the worker.	

Tip tying



Element	Specific system design considerations
	Strong rope control over behaviour of cut piece – anchor point location and good control of rope during rigging is critical.
	Strong rope control may limit ability of cut to influence rigging behaviour, depending on intended outcome. Take care to ensure sufficient hinge wood left – see below.

Additional notes

Tying closer to the tip will result in strong rope control over the cut piece. This can allow branches or tree parts to be supported by the rope, and 'swung' away from obstacles.

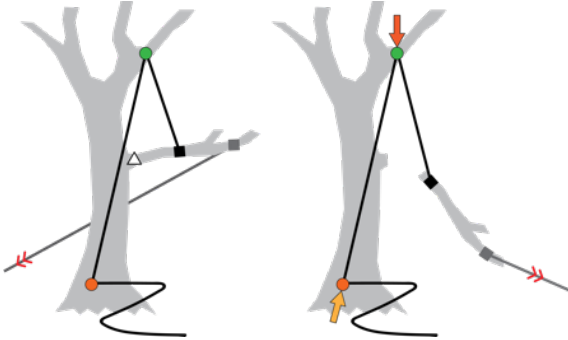
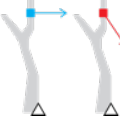
Direction of swing can be influenced by using an angled scarf cut, by using an anchor point in the intended direction of swing, or by using an additional tagline.

Tension in the rope should be managed to control movement of piece – motion such as swing and drop, gradual lower, maintaining tension etc. can all be achieved with proper rope control.

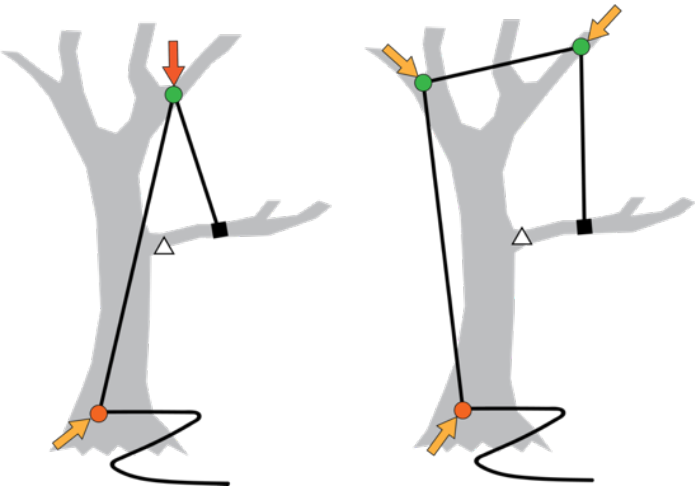
Pre-tensioning rope will help to prevent tip dropping early as it will assist hinge for longer.

Care must be taken when cutting – if the rope is tensioned, the load may not 'drop' as anticipated and there can be a tendency to over-cut or cut through the hinge; in this instance, the butt may drop suddenly and the cut piece may spear back into the trunk (see right hand image above); rope controller must be aware of this possibility and prepared to lower if necessary. Greater responsibility is placed on the rope controller in this setup.

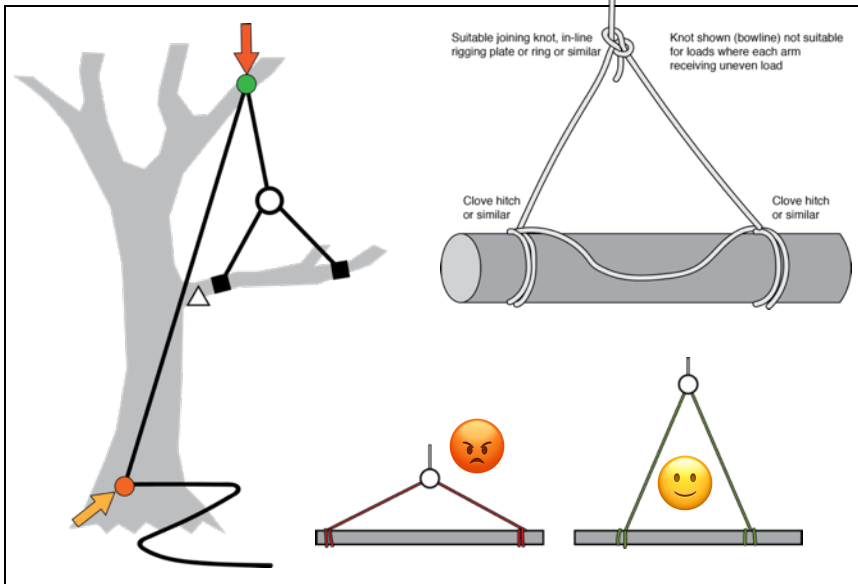
Use of a tagline

	
Element	Specific system design considerations
	Ensure that all components of anchor point are suitable for any additional load that will be applied – pulling large pieces sideways, particularly if using a vehicle or similar, can apply a lot additional force to all components of a rigging system.
	Ensure that tagline will not contact other components of rigging system or any other tree part or nearby object; ensure that sufficient force can be applied at sufficient speed to achieve required outcome. Ensure that tagline can be released quickly if necessary. Injuries and damage have resulted where swinging tree parts have been brought to a sudden stop by taglines or where taglines have been pulled across EWP's or property while under tension.
Additional notes	
	Try to avoid installing and pulling taglines at acute angles to the intended direction of pull. In the image to the left, the blue rope is being pulled perpendicularly to the lever arm of the branch; the red rope is being pulled at an acute angle of around 30°; assuming both ropes are pulled equally, the blue rope will provide around twice as much moment at the hinge.
	Where no additional taglines are available, or to make a 'quick and easy' tagline for a single operation, a mid-line knot such as a clove-hitch on a bight, running bowline tied with a bight, or similar, can be used to attach the rigging line to a branch so that the tail of the rigging line hangs down to be used as a tagline. Before using this technique, ensure that sufficient length of rope is available to lower the piece to the ground.

Use of multiple anchor points

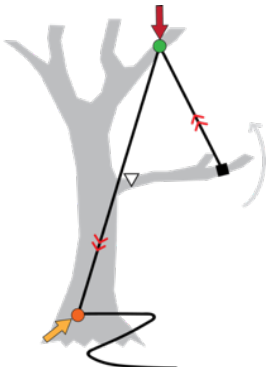
	
Element	Specific system design considerations
	Ensure that force vectors are evaluated at each anchor point for the full range of motion of the intended rigging operation.
	Ensure that the impact on tree structure of compound bending is understood and that the tree structure is suitable for this technique.
Additional notes The use of multiple anchor points can allow tree workers to significantly improve their rigging setups – anchor points can be placed in better locations, applying lower forces with better force vectors to the supporting structure. The two sides of the rope can be separated, avoiding tangling lowered pieces in the rigging line. Compare the single anchor point setup (tree on left) with the multiple anchor point setup (tree on right) – the anchor point has been improved in terms of location and force vector. The placement of anchor points within a rigging setup, and the resulting force vectors, are discussed in detail in Appendix B: Working the angles.	

Cradle rigging

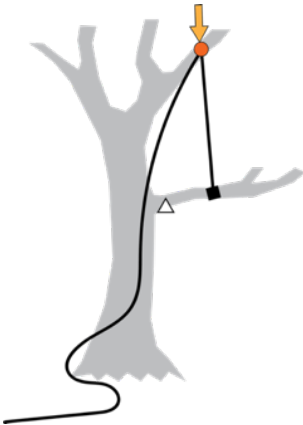


Element	Specific system design considerations
	Attachment rope arms should be joined to main rigging line in a suitable manner with appropriate compatibility of knot and cordage. Ensure that attachment rope arms are joined at a sufficiently acute angle. Large, obtuse angles (greater than 90°) between attachment rope arms may result in significant unanticipated forces within the attachment system (see image above). Use a rigging plate, ring or knot – avoid using a karabiner as this may result in cross-loading and a significant reduction in strength. Take care that attachment method maintains rope strength.
Additional notes	
Cradle rigging can be used to balance branches when working in close proximity to structures. The use of multiple-armed 'spider-leg balancers' can be considered where branches must be balanced across multiple axes. A cradle rigging system can be built out of the end of the main rigging line if necessary (see image to right) – ensure sufficient rigging line remains to lower piece to ground.	

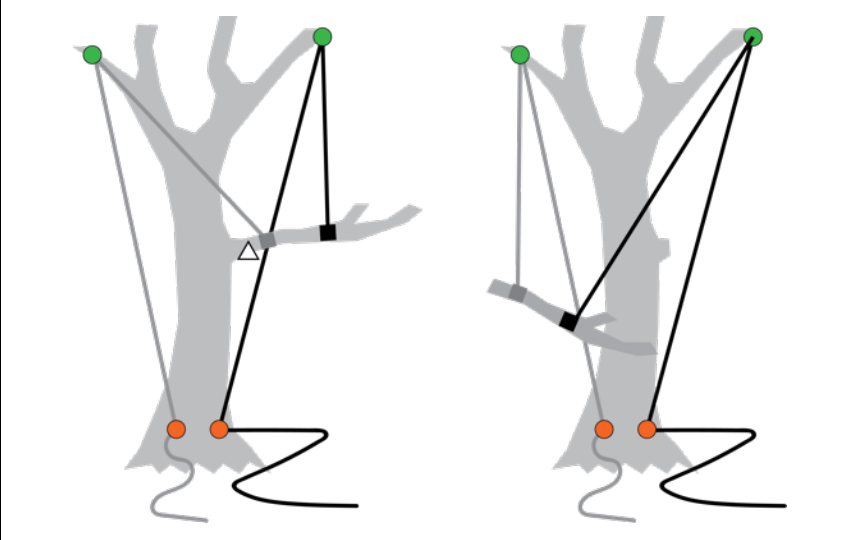
Lifting

	
Element	Specific system design considerations
	Sufficient strength and structural integrity for the additional forces applied when lifting pieces. Force applied to anchor point will vary depending on anchor point friction, size of piece, angle and position of rope attachment to piece, and width of hinge retained.
	Selecting anchor points with minimal friction will help to reduce the resulting forces on the anchor point when lifting; use blocks or pulleys rather than natural-crotch setups where lifting will be conducted.
	Ability to apply force to the rigging rope or capture slack if force applied through another method. Ability to release if necessary.
	Attaching rope closer to tip will aid in lifting operations; Ensure rope attached past centre of gravity – attaching rope too close to butt may result in load inverting during rigging operation.
	Scarf should be aimed upwards or in direction of intended lift. Ensure scarf angle correct – should be obtuse enough to complete lifting operation before hinge breaks if possible; ensure back-cut made to correct hinge to allow lifting operation; over-cutting may result in premature failure of hinge. More vertical sections may be more appropriate to cut with a step cut or similar.

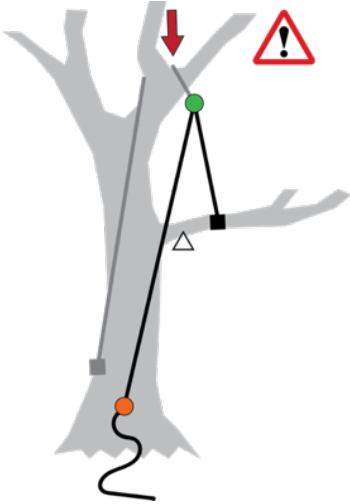
Friction applied at anchor point/s in tree

	
Element	Specific system design considerations
	Suitability for intended use – ease of returning the rope to the aerial worker after each rigging operation, ease of adjustment for the worker when setting the rope
Additional notes Friction is applied to rigging systems to reduce the amount of force that must be held by the crew member controlling the rope This friction is usually applied either at the ground or at the point of cut (see page 138: Applying friction at the point of cut), as applying friction elsewhere can make it difficult to set or return the rope Some manufacturers and climbers are creating and sharing techniques or equipment to apply friction in the canopy above the cut (see aerial friction brake, SafeBloc, rigging wrench, etc.) and still return the rope without effort The application of friction in the tree may remove the necessity for ground crew to apply additional friction Application of friction at the initial anchor point may significantly reduce the magnitude of force applied at this point; these reductions in force are discussed in detail in Appendix B: Working the angles Use of rigging systems like this may make it difficult to pre-tension the line and may prevent any lifting operations Note that friction may be shared between tree and base anchors or as part of more complex systems, as required	

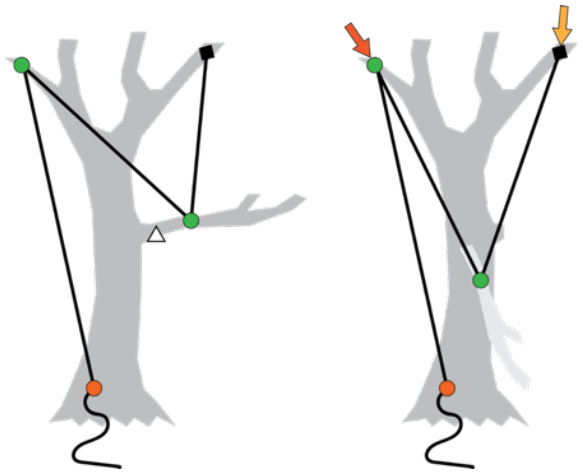
Use of multiple rigging ropes – shared load or load transfer

	
Element	Specific system design considerations
	Ensure that force vectors are evaluated at each anchor point for the full range of motion of the intended rigging operation.
	Simultaneous control of both rigging lines may require a well-trained and experienced ground crew with good communication, and may require additional hardware. Care must be taken to avoid contact between the cut piece and the rigging lines when the piece is moved.
Additional notes	
The use of multiple rigging ropes can allow good control over lowered pieces. This may be a much more efficient and productive setup than trying to swing branches around, struggling to get ropes back to the climber or lowering branches into difficult to access parts of a garden. Although two ropes are shown in the image above, three or more could be used if necessary to control lateral movement during the rigging operation.	

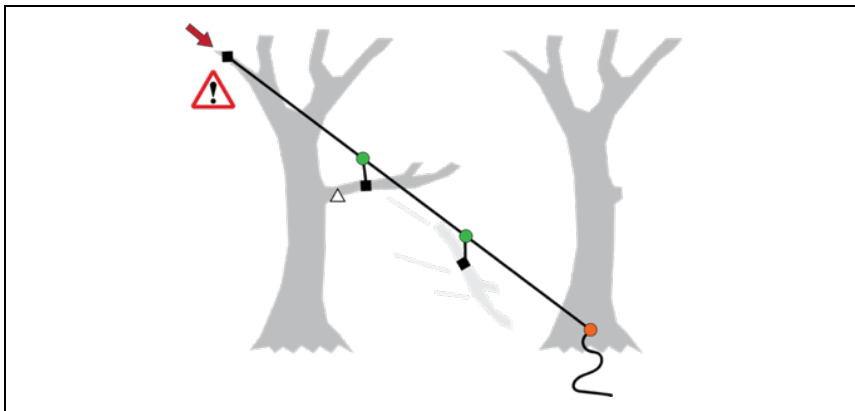
Floating anchor 1: single floating anchor

	
Element	Specific system design considerations
	Floating anchors like this can apply significant forces if used incorrectly. A good understanding of force applications for tree rigging should be acquired before using this or similar techniques; these force applications are discussed in detail in Appendix B: Working the angles.
	Support line (shown in grey) will experience twice the load of the main rigging line; select cordage appropriately.
Additional notes	
Can be a quick and easy way to install a low-friction anchor point such as a lowering block or similar, without needing to access the chosen anchor point location. May quadruple force applied to the tree structure.	

Running anchor 1

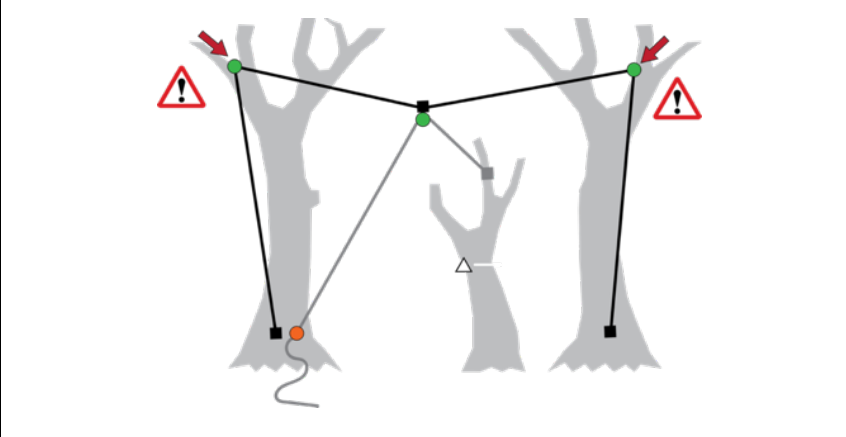
	
Element	Specific system design considerations
	Running anchors like this can apply significant forces if used incorrectly. A good understanding of force applications for tree rigging should be acquired before using this or similar techniques; these force applications are discussed in detail in Appendix B: Working the angles .
	Anchor point must be suitable for the full range of motion that the rigging operation will encompass. Anchor point must allow rope to run smoothly through.
	Force experienced by ground crew (at basal rope brake or by hand) may be 50% or less of load weight.
Additional notes	
The use of running anchor techniques can allow smooth and efficient rigging even in challenging situations, such as where no suitable anchor point exists above a lowering zone or where a significant lateral swing must be avoided. Ensure sufficient rope length is available to lower the piece to the ground. Also known as double-whip tackle, double-whipped tackle, cradle rigging and twin towers rigging.	

Running anchor 2: speed line



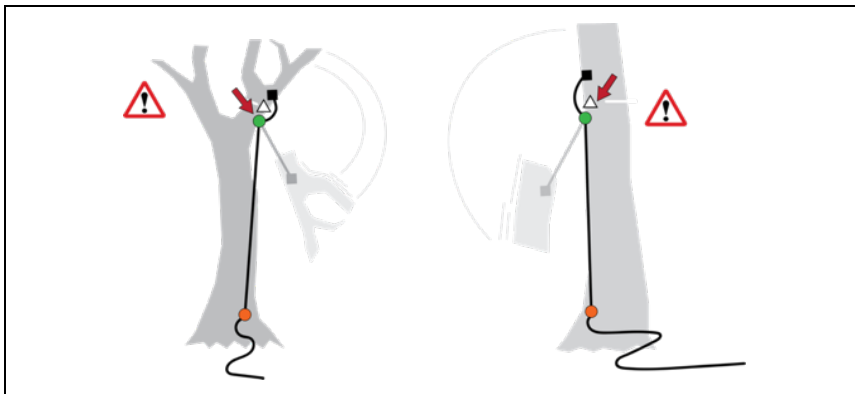
Element	Specific system design considerations
	Very high forces can be placed on all components of a rigging system during speed line operations. A good understanding of force applications for tree rigging should be acquired before using this or similar techniques; these force applications are discussed in detail in Appendix B: Working the angles
	Choice of running anchor point will depend on whether it is returned after each operation If rigging pieces of any significant size, or where failure would have hazardous or damaging consequences, always use a tandem (trolley) pulley or similar it is recommended to implement the use of a 'control line' with 'moving rope anchor point' to take the primary load
	Force experienced at anchor point may be very high
	Force experienced at in-tree attachment point may be very high
Additional notes	
Also known as zip line Many variations of the speed line are possible depending on piece size, crew process ability, anchor point selection, equipment availability, experience and technical difficulty of operation; please see page 160: Speed line or zip line, for more details	

Floating anchor 2: high line

	
Element	Specific system design considerations
	Extremely high forces can be placed on all components of a rigging system during high line operations; forces at in-tree anchor or attachment points may be an order of magnitude higher than expected. A good understanding of force applications for tree rigging should be acquired before using this or similar techniques; these force applications are discussed in detail in Appendix B: Working the angles.
	Good rope selection is critical – ropes for use in high lines should almost always have very low elongation under working loads (static or ultra-static if possible); this avoids needing to pre-tension to cover long spans, although it must be understood that this also removes/reduces the stretch of the rope (its capacity to dissipate the energy generated by a falling piece).
 	Variations of this setup may include multiple high lines to position anchor point in correct location . Anchor point can be fixed, floating or adjustable depending on requirements of rigging operation.
Additional notes	
Many variations of the high line are possible depending on the trees and structures available. The use of high lines for tree rigging or for climbing anchor points can offer a safe, efficient solution to trees that would otherwise be extremely challenging to work in. Please see page 156: Highlines and multiple-point floating anchors, for more details.	

Negative rigging systems

Snatching



Element	Specific system design considerations
	Extremely high forces can be placed on all components of a rigging system during negative rigging. Forces at in-tree anchor or attachment points may be an order of magnitude higher than expected. More details on snatching, including techniques to minimise lateral forces and methods for reducing oscillation, are given on page 144: Snatching.
	Anchor point components must be suitable for dynamic shock loads; avoid the use of single- or double-sheave pulleys in negative rigging configurations. In negative rigging configurations, the cut piece will free-fall for twice the distance between the anchor point and the cut – try to keep the anchor point as tight as possible below the cut.
	Good rope selection may help to compensate for poor control on the part of ground crew; ropes with high elongation will absorb shock load after free-fall – the use of very static ropes should be avoided for all negative rigging.

Additional notes

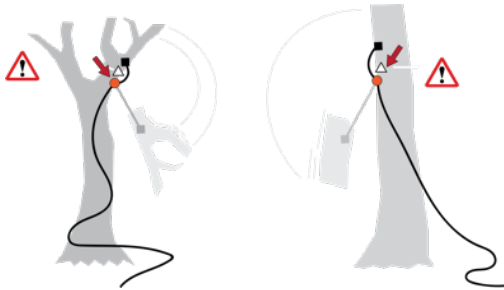
Good control of the rigging line during snatching operations will help to minimise shock loads – try to decelerate pieces smoothly to a stop rather than 'locking them off'.

Eliminate as much slack as possible before making the back cut.

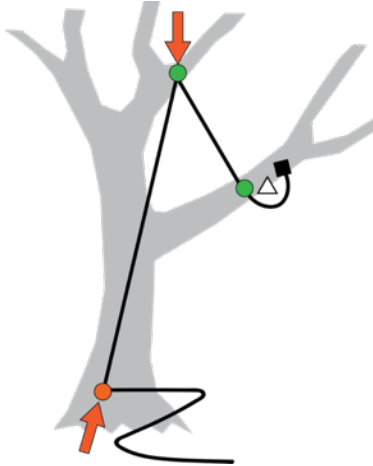
More details on snatching, including techniques to minimise lateral forces and methods of reducing oscillation, are given on page 144: Snatching.

Avoid using pulleys that require metal-to-metal attachments.

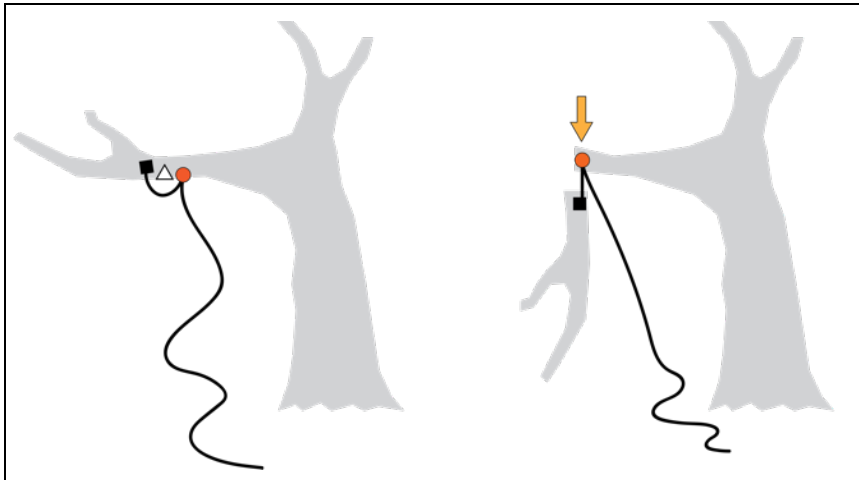
Snatching – friction at point of cut

	
Element	Specific system design considerations
	Extremely high forces can be placed on all components of a rigging system during negative rigging; forces at in-tree anchor or attachment points may be an order of magnitude higher than expected. More details on snatching, including techniques to minimise lateral forces and methods for reducing oscillation, are given on page 144: Snatching.
	Artificial anchor points may be used (Portawrap, SafeBloc or similar), however this technique will normally be used by taking wraps around the tree – rope selection is important; the use of tree wraps should not be considered where the tree part is living and will be retained. Anchor point components must be suitable for dynamic shock loads . In negative rigging configurations, the cut piece will free-fall for twice the distance between the anchor point and the cut – try to keep the anchor point as tight as possible below the cut.
Additional notes	
Good control of the rigging line during snatching operations will help to minimise shock loads – try to decelerate pieces smoothly to a stop rather than 'locking them off'. Eliminate as much slack as possible before making the back cut. More details on snatching, including techniques to minimise lateral forces and methods for reducing oscillation, are given on page 144: Snatching. More details on using friction at the point of cut are given on page 138: Applying friction at the point of cut. The use of this method may reduce the magnitude of peak force compared to the use of a low-friction anchor, however lateral component of force may be increased as the amount of rope in the system is reduced (see Appendix B: Working the angles); use of this method may increase fatigue of the length of rope between the anchor and the cut piece.	

Negative rigging – redirects

	
Element	Specific system design considerations
	Extremely high forces can be placed on all components of a rigging system during negative rigging Forces at in-tree anchor or attachment points may be an order of magnitude higher than expected
	Anchor point components must be suitable for dynamic shock loads; avoid the use of single- or double-sheave pulleys in negative rigging configurations In negative rigging configurations, the cut piece will free-fall for twice the distance between the anchor point and the cut – try to keep the anchor point as tight as possible below the cut
Additional notes	
Good control of the rigging line during snatching operations will help to minimise shock loads – try to decelerate pieces smoothly to a stop rather than ‘locking them off’ it is recommended when working with lateral branches that they be tied on before beginning cut. This may require the use of a marlinspike on the rope to allow saw access during bottom cut/scarf Eliminate as much slack as possible before making the back cut Ensure that rigging lines between the lower anchor point and the branch attachment point do not become tangled or wrapped around the stub	

Friction at the point of cut 1: negative branch rigging



Element	Specific system design considerations
	Artificial anchor points may be used (Portawrap, SafeBloc or similar) but this is uncommon This technique will normally be used by taking wraps around the tree – rope selection is important; the use of tree wraps should not be considered where the tree part is living and will be retained Anchor point components must be suitable for dynamic shock loads In negative rigging configurations, the cut piece will free-fall for twice the distance between the anchor point and the cut – try to keep the anchor point as tight as possible below the cut

Additional notes

Good control of the rigging line during snatching operations will help to minimise shock loads – try to decelerate pieces smoothly to a stop rather than 'locking them off'

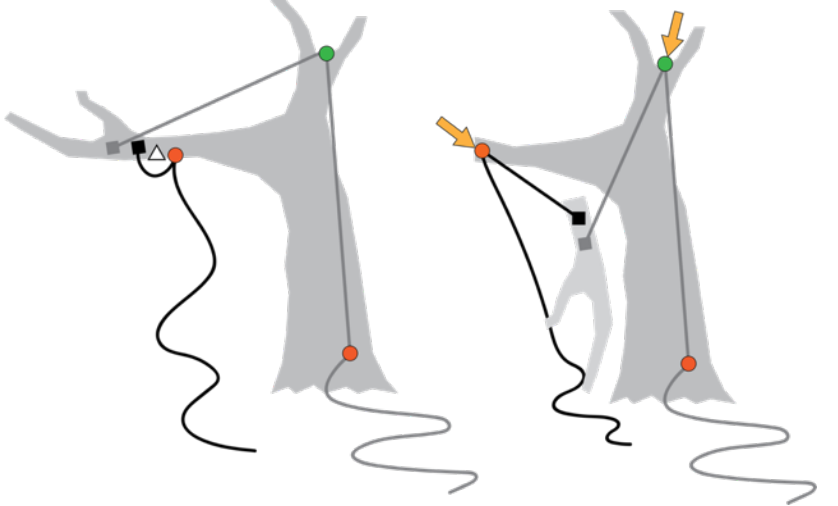
Eliminate as much slack as possible before making the back cut

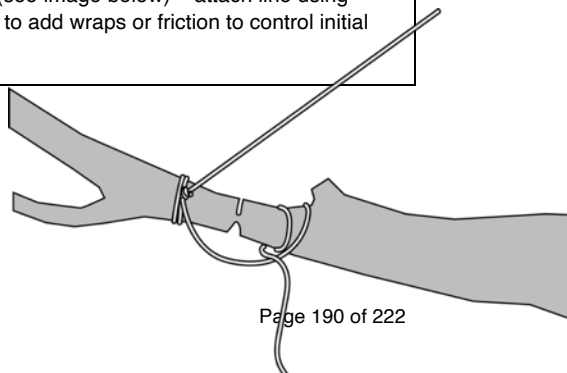
While some shock load can be anticipated, the reduction in lever arm caused by the end weight moving from 'held outward' to 'hanging below' will usually cause the branch to sit up; do not attempt this technique with a low-friction anchor and friction at the base of the tree without using a redirect, multiple anchor point technique or similar – you may break branches!

Ensure that branch structural integrity is suitable for dynamic loading.

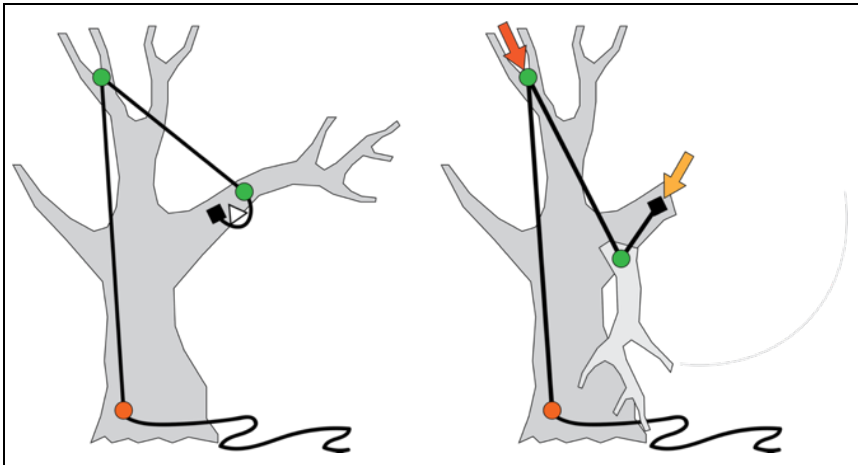
Tree structure must be suitable to use this technique. A stub or union to site the rope will usually be required. Wraps may 'fall off' downward sloping branches.

Friction at the point of cut 2: transferring loads

	
Element	Specific system design considerations
	Artificial anchor points may be used (Portawrap, SafeBloc or similar) but this is uncommon This technique will normally be used by taking wraps around the tree – rope selection is important; the use of tree wraps should not be considered where the tree part is living and will be retained Anchor point components must be suitable for dynamic shock loads In negative rigging configurations, the cut piece will free-fall for twice the distance between the anchor point and the cut – try to keep the anchor point as tight as possible below the cut
Additional notes • A good way to deal with branch removal where excessive swing will be a problem • Makes it easy and efficient to return the rope to the climber • Can be completed using tail of main line (see image below) – attach line using midline knot, with sufficient tail remaining to add wraps or friction to control initial movement.	

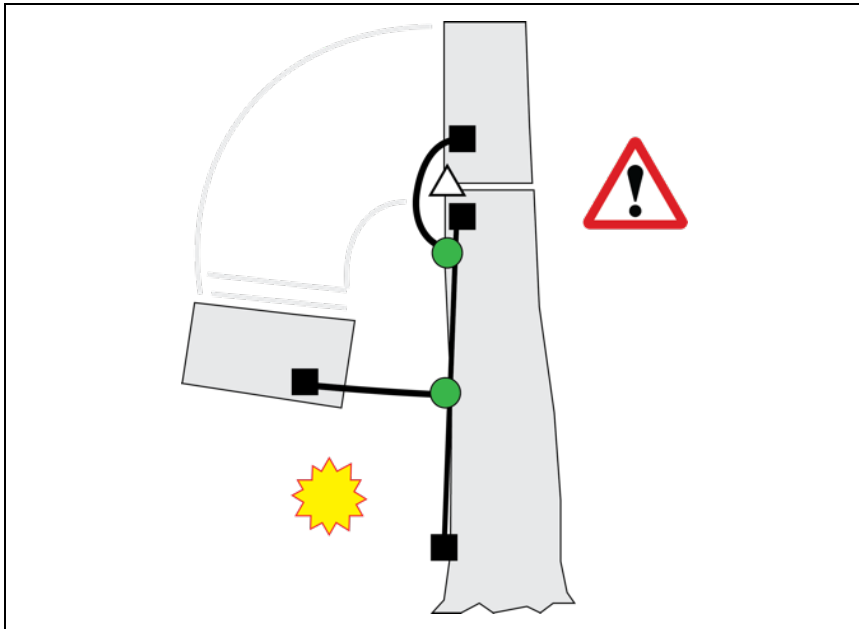


Running anchor 3: negative rigging



Element	Specific system design considerations
	Running anchors like this can apply significant forces if used incorrectly. A good understanding of force applications for tree rigging should be acquired before using this or similar techniques; these force applications are discussed in detail in Appendix B: Working the angles .
	Choice of running anchor point will depend on whether it is returned after each operation. If rigging pieces of any significant size, or where failure would have hazardous or damaging consequences, always use a tandem (trolley) pulley or similar.
Additional notes	
A good way to deal with branch removal where excessive swing will be a problem Makes it easy and efficient to return the anchor to the tree worker – simply detach the running anchor from the cut piece and pull on the tail of the rigging line until the anchor slides back to the attachment point where the last cut was made A quick way to deal with extended branches, particularly where the main anchor point is a long way away or returning the rope is difficult	

Vertical speed line



Element	Specific system design considerations
	Extra care must be taken when installing vertical speed line setups – installing life support support anchors on top of speed line components will be fatal Forces generated in vertical speed line are hard to predict and may be extremely high due to deflection force as piece comes off and moves laterally, or if piece impacts stub or root flare and is bounced sideways
	Choice of floating anchor point will depend on whether it is returned after each operation Anchor point components may be damaged during vertical speed line operations
Additional notes	
The use of vertical speed lines is often considered where dropped pieces may bounce or roll when hitting the ground Vertical speed line operations can result in very high peak forces. Do not assume that because one piece went smoothly, the next will behave in exactly the same way!	

Appendix B: Working the angles

It can be extremely difficult to accurately model forces during real-world rigging operations. Factors such as friction, shock load, elastic elongation, branch flex and taper, unquantifiable decay pockets, compromised branch unions, unseen defects and decayed timber are all factors not included in these workings. All these calculations become somewhat redundant when the 'real strength' of tree is unknown.

In addition, tree workers are almost always dealing with unknown or hard-to-know working loads, particularly during dynamic rigging operations, which makes the use of mathematics and modelling a somewhat futile exercise. Finally, the behaviour of the ground crew member controlling the rope is almost always unpredictable!

Nevertheless, an understanding of the physics behind a lot of what we do in the practical world gives the opportunity to understand and think about things in much greater depth. Particularly when presented with a challenging practical problem, understanding the principles behind the suggested setups and practices shown previously in this MIS may allow calculation of which of several possible options generates the best force on a tree or provides the most useful force for the work to be conducted.

This appendix will look at the mathematical principles that underpin the scenarios given previously and is intended to provide the tools for tree workers to apply these principles in a greater range of situations than the limited scope afforded here.

Introduction to forces

To understand and consider the forces which are applied to the structure of the tree, it is necessary to introduce some simple units of physics.

Force

Newtons (N)

Any interaction which if unopposed will change the motion of an object. One newton is the amount of net force required to accelerate a 1 kg mass by 1 m/s².

A weight in kilograms can be converted into the downward force applied by the weight of that object by multiplying the weight by the force of gravity (9.81m/s²)

Lever arm

Metres (m)

The distance between the point of application of a force and an axis of rotational movement.

Bending moment

Newton metres (Nm); or
Kilonewton metres (kNm)

The rotational effect caused on a point by a force that is applied at a given distance away from that point along a lever arm.

Force multiplied by length.

Working in newtons

Working in newtons

One newton is the amount of net force required to accelerate a 1 kg mass by 1 m/s².

In this MIS, gravity has been approximated as 10 m/s², therefore a 1 kg mass exerts a downward force of 10 newtons (N).

Where equipment has a rating printed in kilonewtons (kN), it can be divided by approximately 10 (approximation of acceleration of gravity) if it is easier to think about its strength in kg, although the outcome is not really meaningful.

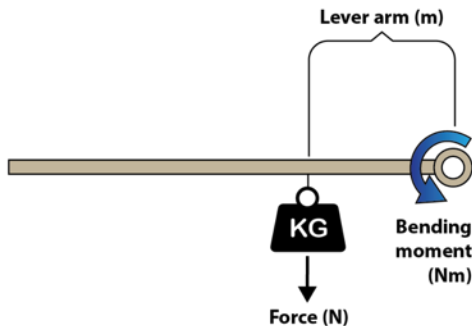
Nevertheless, for arborists comparing two pulleys it can be helpful to think that:

MBS of 22 kN =

MBS of 2,200 kg =

WLL of 220 kg, assuming a safety factor of 10.

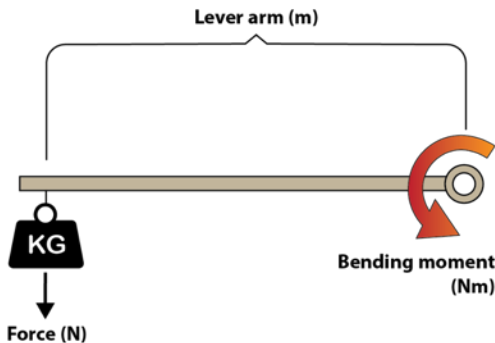
Force, lever arm and bending moment



The images on the left show how force, lever arm and bending moment are related.

A force, in this case applied by hanging a weight from a beam, applies a bending moment to the fulcrum or axis at the end of the beam.

As the weight is moved out along the beam, the length of the lever arm increases, and the bending moment applied at the fulcrum increases proportionately.



This relationship would be familiar to anyone who has used a crowbar, or used a tag line to pull over a tree which is being felled. An increase in the length of the lever arm will increase the force applied at the fulcrum.

A good understanding of force, lever arm and bending moment is critical when comparing rigging systems for use in trees.

It is important to be aware of the **direction** or **vector** of the force which is applied to the tree. Forces which act in a perpendicular (90°) direction to the axis of the lever arm apply significantly more bending moment than forces which act at an acute angle to the axis.

In order to calculate the actual bending moment applied at a point, the angle between the lever arm and the applied force must be considered.

Lever arm

Previously in this MIS, lever arm was defined as:

Length of lever arm x component of force applied perpendicular to lever arm

In order to calculate the actual moment applied at a point we need to include the angle between the lever arm and the applied force. The equation to do so is:

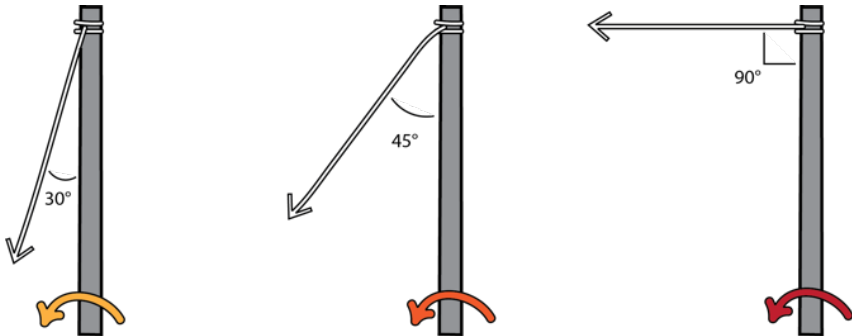
Calculating moment – forces acting on lever arms

$$M = r F \sin \theta$$

- M** is the bending moment applied at the base of the tree
- r** is the distance from the base to the centre of gravity
- F** is the magnitude of the force being applied, in this case the weight of the whole stem multiplied by the force of gravity (9.81m/s²)
- θ** is the angle between the force and the arm. To allow for dynamic loading a minimum θ of 30° should be used even if the stem is more vertical.

The outcome **M** is a measurement of the bending moment applied at the base of the lever arm and is expressed in newton metres (Nm).

The three examples below compare the use of a tag line to assist with felling a tree. In each case, the tag line is pulled with the same force, roughly equivalent to a 100kg person applying their full weight onto the rope.



Assuming that in every case above, the length of the stem is 10 m and the force applied is 1 kN (≈ 100 kg).

$M = rF \sin \theta$ $M = 10 \times 1000 \sin 30$ $M = 10,000 (0.5)$ $M = 5,000$ Nm (newton metres)	$M = rF \sin \theta$ $M = 10 \times 1000 \sin 45$ $M = 10,000 (0.71)$ $M = 7,071$ Nm (newton metres)	$M = rF \sin \theta$ $M = 10 \times 1000 \sin 90$ $M = 10,000 (1)$ $M = 10,000$ Nm (newton metres)
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It is not expected that this calculation will be required frequently during regular tree work, however it may prove useful when conducting complex lifting operations or during crane work.

Force vectors at anchor points

Again, the equations below are provided to assist tree workers with developing new systems rather than because they should be used in day-to-day rigging operations.

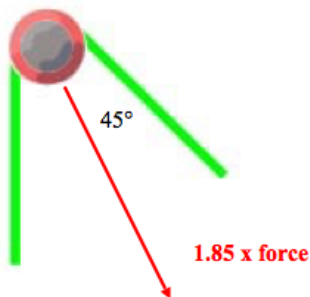
Calculating moment – forces acting on lever arms

The net force **F** on a point will bisect the angle made by the rope at that point such that:

$$F^2 = 2X^2 + 2X^2\cos a$$

Where **X** is the force on the rope and **a** is the angle made by the rope across the point.

In the examples given below, the pulley is assumed to have no friction (perfectly efficient) and the rope is holding a mass of 100 kg, with one end tied off at an anchor.



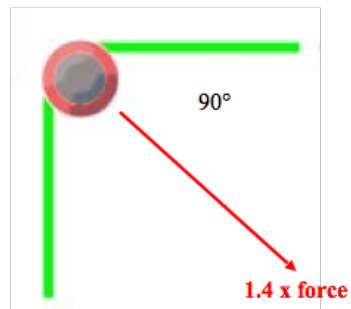
$$F^2 = 2X^2 + 2X^2\cos a$$

$$F^2 = 2(1000)^2 + 2(1000)^2\cos 45$$

$$F = \sqrt{(2,000,000 + 1414213)}$$

$$F = 1848 \text{ N}$$

$$F = 1.85 \times \text{Force}$$



$$F^2 = 2X^2 + 2X^2\cos a$$

$$F^2 = 2(1000)^2 + 2(1000)^2\cos 90$$

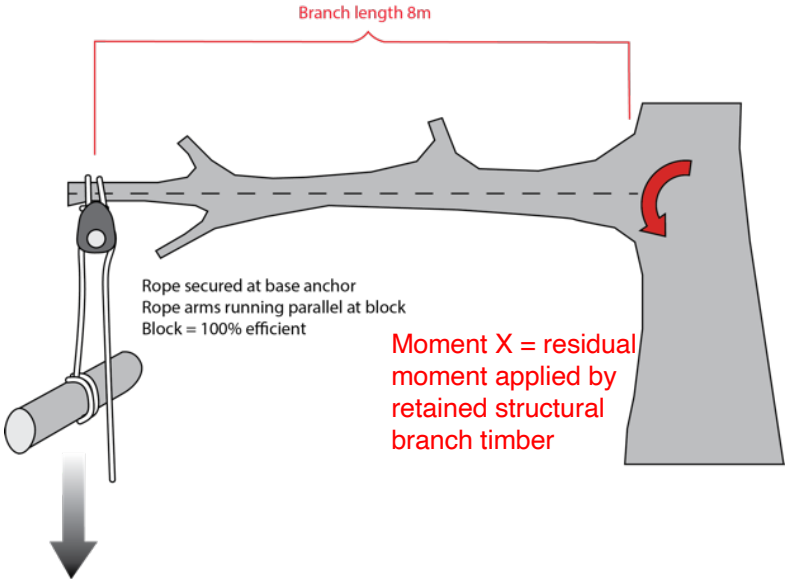
$$F = \sqrt{(2,000,000 + 0)}$$

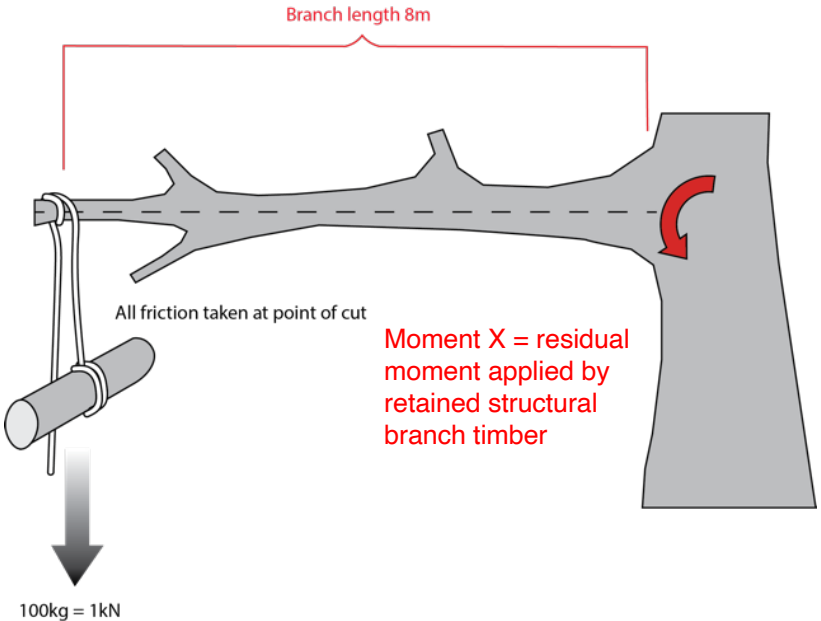
$$F = 1414 \text{ N}$$

$$F = 1.4 \times \text{Force}$$

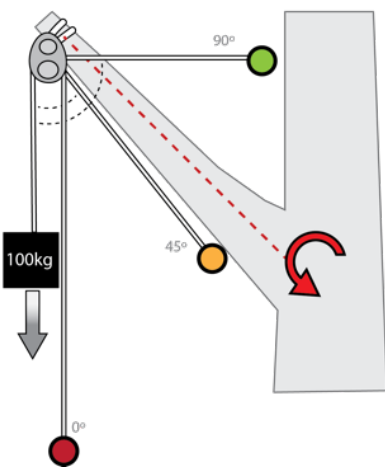
Working the angles I – rigging a branch section onto itself

The worked examples below are intended to illustrate the process of using these equations, as well as to show some possible applications.

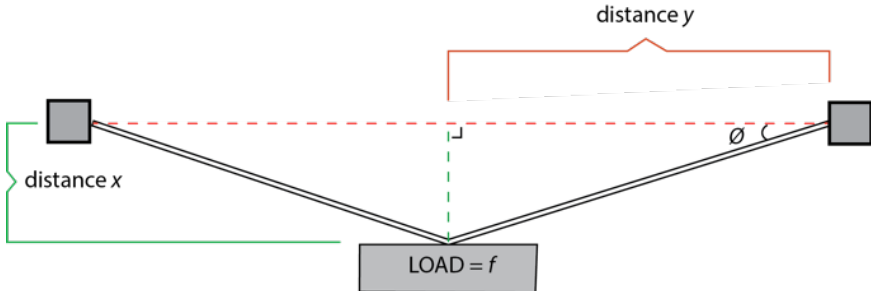
Using a pulley at the point of cut	
 Branch length 8m Rope secured at base anchor Rope arms running parallel at block Block = 100% efficient 100kg = 1kN Moment X = residual moment applied by retained structural branch timber	
Moment applied at union by section before cut	$M = r F \sin\theta$ $M = 9.5\text{m} \times 1\text{kN} \times \sin 90$ $M = 9.5 \text{ kNm}$
Moment applied at union by section after it is brought to a stop	$M = r F \sin\theta$ $M = 8\text{m} \times 2\text{kN} \times \sin 90$ $M = 16 \text{ kNm}$
Difference in moment applied	$M = 16 - 9.5 \text{ kNm}$ $M = 6.5 \text{ kNm}$
Branch behaviour after section brought to a stop	Branch will drop – climbing lines above will go extremely taut, branch may fail

Friction at the point of cut	
 Branch length 8m All friction taken at point of cut Moment X = residual moment applied by retained structural branch timber 100kg = 1kN	
Moment applied at union by section before cut	$M = r F \sin \theta$ $M = 9.5\text{m} \times 1\text{kN} \times \sin 90$ $M = 9.5 \text{ kNm}$
Moment applied at union by section after it is brought to a stop	$M = r F \sin \theta$ $M = 8\text{m} \times 1\text{kN} \times \sin 90$ $M = 8 \text{ kNm}$
Difference in moment applied	$M = 8 - 9.5 \text{ kNm}$ $M = -2 \text{ kNm}$
Branch behaviour after section brought to a stop	Branch will lift – climbing lines above may go slack.

Working the angles II – force vectors and moment

Force vectors and moment		
branch length $l = 5\text{ m}$  l Branch length (5 m) a Angle between rope arms $\emptyset$ Angle between lever arm and resulting vector M Moment applied at union		
Lines running parallel	45° between lines	90° between lines
$M = l \sqrt{(2F_2^2 + 2F_2 \cos a)} \sin \emptyset$	$M = l \sqrt{(2F_2^2 + 2F_2 \cos a)} \sin \emptyset$	$M = l \sqrt{(2F_2^2 + 2F_2 \cos a)} \sin \emptyset$
$M = 5 (2\text{kN}) \sin 45^\circ$	$M = 5 (1.8\text{kN}) \sin 22.5^\circ$	$M = 5 (1.4\text{kN}) \sin 0^\circ$
$M = 7 \text{ kNm}$	$M = 3.5 \text{ kNm}$	$M = 0 \text{ kNm}$

Deflection forces



Calculating deflection forces method 1

Where a load f is suspended between two points at equal height, equidistant from either point, the magnitude of the force F on each point is given by

$$F = \frac{f}{2\sin\theta}$$

Where θ is the angle made between the rope and an imaginary horizontal line between the two points. This can also be written as:

$$F = \frac{f\sqrt{x^2 + y^2}}{2x}$$

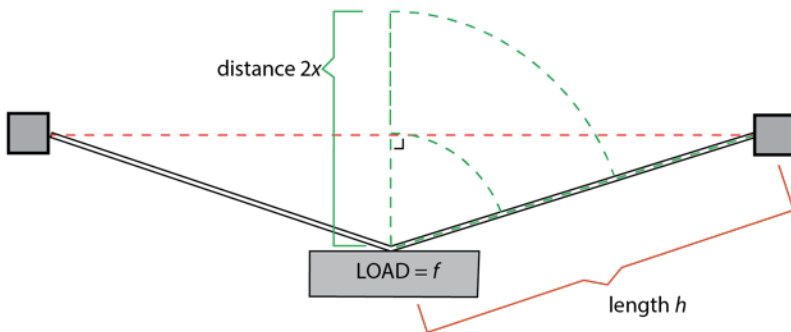
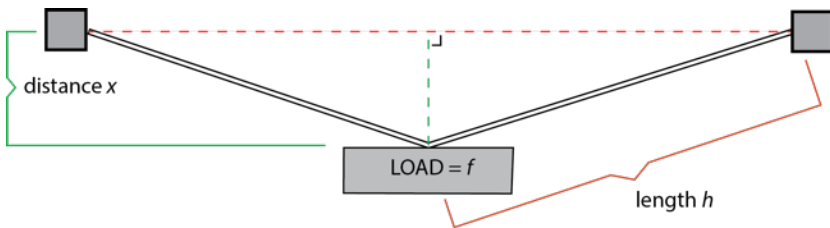
Where x is the vertical distance that the rope has deflected below the horizontal and y is the horizontal distance of the load from each point.

Calculating deflection forces method 2

Where a load **f** is suspended between two points at equal height, equidistant from either point, the magnitude of the force **F** on each point is given by

$$F = f(h : 2x)$$

Where **h** is the length of rope between the anchor point and the load, and **x** is the distance that the load is suspended below an imaginary straight line connecting the two anchor points



$$F = f(h : 2x)$$



Glossary

12-strand rope	a rope construction consisting of 12 braided strands and no core
16-strand rope	braided rope construction with a strength-carrying cover and a filler core
3-strand rope	a rope construction consisting of three strands twisted together in a spiral pattern
abrasion resistance (of rope)	the endurance of a particular cordage material or construction when subjected to wear
acceleration	the rate of change of speed of an object
adjustable balancer	adjustable rigging sling used to balance limbs in removal operations
anchor	in rigging, the point where the rigging system is tied off or where friction is controlled
anchor block	in a mechanical advantage system that employs pulleys, the stationary block in a block and tackle system
anchor force	the sum of the forces acting upon the anchor point/s in a rigging system
anchor hitch	a knot commonly used to attach a line to a piece of hardware
arborist block	heavy-duty pulley with an integrated connection point (bushing) for attaching a rope sling, a turning sheave for the rope and extended cheek plates; used in tree-rigging operations
axis or axes (of loading)	a direction in which a component can be loaded
back cut	the last in a series of cuts used in felling or limb removal, made on the opposite side of a log toward the notch cut or face cut
balance	in rigging, a technique used to lower a limb without allowing either end to drop

balancer	rigging sling/s, usually with at least one spliced eye and a prusik to position the load line, used to rig a limb in a balanced configuration (see spider-leg balance)
barber chair	dangerous condition created when a tree or branch splits longitudinally (vertically) up from the back cut
bearing	in a block or pulley, the area of contact between the sheave and the axle
becket	a secondary attachment point on a pulley
beer knot	a knot commonly used to join two ends of tubular webbing
belay device	a piece of equipment used to provide friction for belaying a climber
bend radius	the radius of an object around which a line passes
bend ratio	the ratio of the diameter of a branch, sheave or other device to the diameter of the rope that is wrapped on it
bight	a curve or arc in rope
block	a pulley used in rigging, designed for dynamic loading
blocking	a method of using an arborist block to rig down trunk sections (butt hitching)
bollard	a post on which wraps can be taken with a rope to increase friction
bore cut	a back-cut technique in which the hinge is established by plunge cutting through the stem, then cutting back away from the hinge
bowline	a looped knot used to attach items to a rope
bowline on a bight	a knot used to form two loops in the standing part of a rope
braided rope	rope construction in which the strands or yarns are woven together in a diagonal pattern
breaking strength	the force at which a piece of equipment or rope fails under a static load
buntline hitch	a simple hitch commonly used to attach a line to a piece of hardware

bushing	a metal tube that acts as a guide or bearing for moving parts such as the axle and sheave of a pulley; or the non-rotating sheave used to increase the bend radius for the sling attachment
butt-hitching	method of lowering pieces when the rigging point is below the work (traditionally, without the use of a block)
butt-tying	tying off a limb at the butt end for rigging
butterfly knot	a knot that can be used to form a loop in the standing part of a line
cavity	an open wound or hollow within a tree, usually associated with decay
clevis	see shackle
clove hitch	a knot used to secure an object to a rope
configuration	the manner in which a component is connected to other parts of the rigging system or the manner in which it is used or loaded.
conk	the fruiting body of a fungus, often associated with decay
connecting link	a component of a rigging (or climbing) system that connects other components together
control line	in speed-lining, the line used to control the descent of the load on the speed-line and to retrieve the pulley or traveller assembly
cow hitch	a knot commonly used to attach hardware to a tree, generally backed up with a half-hitch
cycles to failure	the number of times a rope or other piece of equipment can be used with a given load before it fails
dead-eye sling	a rope sling with a single eye spliced in one end
design factor	the factor by which the rated or minimum breaking strength of the rope is divided in determining its working load limit
displacement	the vector form of distance involving direction as well as magnitude

double braid	a rope construction that consists of a braided rope within a braided rope
double fisherman's bend	a knot commonly used to join two ropes or two ends of the same rope, as when forming a prusik loop
double-locking	with a karabiner or snap, requiring two distinct motions before opening
drift line	a variation on the load-transfer technique in which the load is transferred to a second line and moved to another point, often to a second tree
drop cut-branch	a removal technique consisting of an undercut and a top cut farther out on the branch
dynamic loading	forces created by a moving load, the force of which, changes with time and motion
dynamics	the study of how objects move under the action of forces
dynamometer	an instrument for measuring mechanical force
elastic energy	kinetic energy, which is temporarily stored in a body or a system and is conserved as elastic potential energy
elongation, or elastic elongation	the proportion of its length that a part of cordage will extend under a given load
end line loop	a loop created in the end of a rope by forming any of numerous knots
energy	the potential to do work
eye splice	termination in a rope forming an eye and made by splicing the end of the rope back into itself
eye-to-eye sling	a length of rope spliced with an eye at each end
fall	a part of the rigging line from the rigging point to the anchor point
false crotch	a pulley or other device set in a tree to support a climbing or rigging line
fibre	smallest element of a rope
fixed loop	webbing or rope sling that consists of a complete, closed loop

fixed rope anchor point	the point where a rope is tied or secured to a tree part or other anchor.
fixed-eye sling (short)	a length of rope with an eye spliced in one end
fixed-length balancer	a sling, used in balancing limbs for removal that is not adjustable in length
floating anchor	anchor point in a rigging system that can be moved anywhere between two points
foot lock	a method of ascending a rope to gain entry into a tree
force	the action of one object on another
French prusik	a type of friction hitch used in climbing and rigging
friction	a specific type of force that resists the relative motion between two objects in contact; the direction is always opposite the motion
friction device	a device used to take wraps in a load line; provides friction for controlled lowering
girth hitch	a simple knot used to attach a line, spliced eye or endless loop to an object
half-hitch	a simple knot used to temporarily secure a line to an object; also used as a backup in combination with other knots
hinge	a strip of wood fibres created between the scarf and the back cut that helps control direction in tree felling or limb removal
hinge cut	a sequence of cuts used to control the direction of a limb being removed
hollow braid	a braided rope construction having an empty centre
input force	the force applied initially to a system
karabiner	oblong metal ring, used in climbing and static rigging that is opened and closed by means of a spring-loaded gate
Kernmantle	rope manufactured with a strength-carrying core to have a core and braided sheath
key lock	in karabiners, a specific configuration of the latch designed not to catch on ropes

kinetic energy	the energy an object has due to its motion
knotless system	a rigging system in which loop slings and connecting links are used to attach branches or wood sections to the lowering line
knotted strength (of rope or slings)	the reduced strength of a particular cordage type when a knot is incorporated into the loaded section
lead	the part of the rigging line from the rigging point to the load
lifting	a rigging technique in which the tip of a branch is raised up before lowering in order to avoid obstacles below lifting cut; a variation of the hinge-cut technique used to cut limbs that are being lifted
load binder	a strapping device used to secure loads
load line	rope used to lower a tree branch or segment that has been cut
load-transfer line	a rigging technique in which a second load line is used and the weight of the branch or wood section is transferred from the initial load line to the second
loop	a bight that crosses itself or a bight made fast with a knot
loop knot	any of numerous knots that can be used to form a loop in a line
loopee	a specific type of sling made up as an adjustable loop
lowering device	brand name of an instrument attached to the base of a tree in rigging; used to take wraps with the load lines to provide friction for controlled lowering line-see load line
marline hitch	a simple hitch used in lashing; in rigging, a secondary knot used in combination with a primary attachment knot to tie-off sections for lowering
marling	the act of forming a marline hitch in series along an object
mechanical advantage	a system by which effort can be multiplied
mechanics	the study of forces and their effects on bodies at rest or in motion
method	use of specific equipment combined with basic techniques

midline loop	a loop made fast with a knot formed in the standing part of a line
minimum breaking strength	also known as minimum break strain and usually expressed in Kilonewtons (kN), this figure is the load above which an item of lifting equipment can be expected to fail when new and when used in the correct configuration; this number will drop rapidly i.e. the equipment will break much sooner than expected such as when using old, worn, damaged or mis-configured equipment
mismatch cut	see snap cut
moment	the twisting action caused by a force acting some distance from a pivot point
moving block	in a mechanical advantage pulley system, the pulley that moves
moving rope anchor point	a moving rope anchor point is part of a rigging system where a loaded rope makes an angle and can be supported but will still be able to move freely across that angle; examples include pulleys, rigging rings, tree unions, rigging blocks
natural-crotch rigging	rigging methods that utilise natural crotches for the rigging points
point of cut	the place where a cut will be made during a rigging operation – can be scarf, step cut or other
PortaWrap	a device used to create and manage friction in the lowering line (load line) in rigging operations; potential energy – the stored energy an object has due to its position (in relation to a fixed horizontal plane)
prusik	see prusik hitch
prusik hitch	a type of multi-wrapped friction hitch used in climbing and rigging; used to attach the prusik loop to the climbing line when footlocking
prusik loop	a loop of rope used to form a prusik hitch for climbing or rigging
prusik minding	a specific type of pulley configured with extended cheek plates to keep a prusik from jamming in the sheave

pull line	a tagline or a line tied near the top of a piece or tree to be removed and used to help pull the top in the desired direction
pulley	a device consisting of a rotating, grooved wheel between two side plates; used to change the direction of pull in a line
ratcheting bollard	a bollard-type lowering device equipped with a mechanism for lifting loads
reaction force	a force of equal magnitude exerted in the opposite direction to a force acting on a body
recommended rope diameters	for some hardware such as blocks, pulleys and bollards, the manufacturer may provide a recommended range of rope diameters; may be printed on the device (sometimes shown as Φ or Φ) or can be found in the manual; exceeding the recommended rope diameter may result in abrasion of hardware, damage to rope or reduction in rope strength (see bend ratio)
redirect rigging	changing the path of a rigging line to modify the forces or alter the direction of limb removal
rescue pulley	a light-duty pulley used in rigging operations
resultant	a single force equal to the sum of all forces acting on an object
rigging	a method of using ropes and hardware to remove large limbs or to take down trees
rigging point	the place in the tree (natural or false crotch) that the load line passes through to control limb removal in rigging operations
root flare	the portion of a tree where the trunk flares out into the root system
rope bag	a bag used to store climbing and rigging lines
rope brake	a part of a rigging system through which a loaded rope is able to move where friction has been deliberately added to allow control over the movement of the load; examples include wraps around a tree, Portawraps, rigging bollards
rope sling	a section of rope, usually with at least one eye splice, used to secure equipment or tree sections in rigging operations
round turn	two turns of a line around an object

running bowline	a knot often used to tie-off limbs for removal
running end	the end of a rope not in use
scarf	a wedge-shaped cut forming the front of the hinge used in felling or limb removal
screw link	a connecting device with a threaded closure mechanism; used in rigging operations
screw lock	a locking mechanism for a connecting link such as a karabiner
shackle	a U-shaped fitting with a pin run through it; clevis
sheave	the inner fitting within a block over which the rope runs
sheet bend	a knot used to attach two lines; the lines can be of unequal diameter
sling	a device used in rigging to secure equipment or pieces being rigged
slip knot	a slipped overhand knot
slipped (in knots)	having a bight of rope passed through the final tuck in a knot to provide for quick release
slippery bend	a knot used to attach two lines; can be released quickly by pulling on the final tucked bight
snap cut	a cutting technique in which offset, bypassing cuts are made so that a section can be broken off manually; mismatch cut
speed-line	a rigging line strung in such a way as to slide tree segments to the ground
spider balancer or spider-leg balancer	a system utilising multiple slings to lower a large limb with a wide spread without allowing either the butt or any of the tips to swing or drop down when the limb is cut
spliced eye	see eye splice
spliced strength (of rope or slings)	strength of the rope when the splice is incorporated into the loaded system
spliced-eye sling	a length of rope with an eye spliced in the end
standing part	the inactive part of a rope, as opposed to the working end

starting corner	the lower front tip of a chainsaw bar, used to begin a bore cut
static removable (retrievable) false crotch	false crotch, usually an arborist block, that can be set in a tree and removed from the ground
statics	the study of forces in equilibrium
strand	the largest component of a rope; yarns are twisted to form strands, and strands are twisted (usually in the opposite direction) or braided to form rope
tagline	a rope used to control the swing of a limb being removed; a rope used to control the direction or fall of a tree or limb being removed
technique	a means of accomplishing a task
tensile strength	force at which a new piece of equipment or rope fails under a static load in testing
timber hitch	knot consisting of a series of wraps on a rope; used to secure the rope to a limb or tree
tip-tying	tying a rope on the tip (brush) end of a limb to be removed
topping	in rigging, removing the top from a tree
topping cut	a hinge cut used when removing the top from a tree
turn	one wrap of a rope around an object
undercut	a cut on the underside of a limb being removed to prevent unwanted tearing as the limb falls
Valdôtain tresse (Vt)	a variation of the French prusik used as a friction hitch in climbing and rigging
vector	graphical representation of quantities that have both a magnitude and a direction
water knot	a variation of the overhand knot used in joining ends of webbing slings
webbing sling	length of sewn webbing, often formed into a loop, used as an attachment in rigging
weight	force created by the action of the earth (gravity) on an object

whoopie sling	a sling with one fixed eye and one adjustable eye, made from hollow-braid rope
work	a force causing an object to move some distance (displacement)
working end	the end of a rope in use
working load	the load that is applied to a rope in normal service
working load limit	the maximum recommended load a piece of equipment should experience when correctly configured during regular operations; WLL can be calculated by tensile strength divided by design factor; maximum load that should not be exceeded in a rope or rope assembly when performing its normal working function
wrap	passing a rope around an object (usually a friction device or some part of a tree) to create friction to control a heavy load in a rigging operation
yarn	the component of a rope formed from twisted fibres; yarns are then twisted into strands
Zeppelin bend	knot used to join two ropes

Notes and References

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Minimum Industry Standards

This document is one in a series of Minimum Industry Standards (“**MIS**”) produced by Arboriculture Australia Ltd in partnership with the New Zealand Arboricultural Association and the wider arboriculture community to ensure that all people working, assessing and providing advice in relation to trees (excluding commercial forestry) have access to industry peer-reviewed documents explaining the core standards of skills and equipment with which competent practitioners should be familiar.

Where a MIS exists for a particular task, it is deemed by industry experts to:

- Provide an overview of the task, as it is practiced in industry.
- Define an industry consensus regarding the current appropriate applied-practice ways of conducting that task.
- Specify the minimum skill and knowledge requirements for performing particular tasks in the workplace.

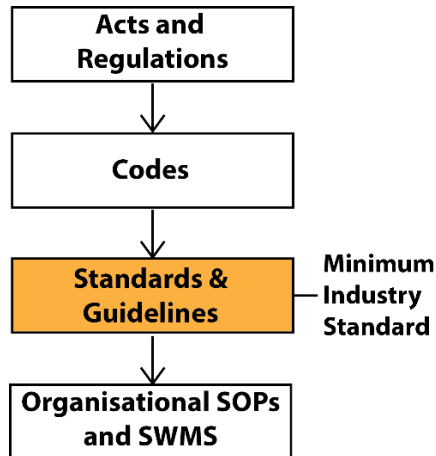
At times, the complexity of a task may surpass the level of skill described in a MIS. It is the practitioner’s responsibility to clearly understand and interpret the level of skill described in the MIS and whether that level is adequate for the task before them. In many cases a person will need to refer to several MIS documents to complete one task.

The prime purpose of the MIS is to provide minimum standards for the safety of tree workers, while still encouraging and fostering innovative practices.

Equipment, tests, inspection or practices other than those in this document may be perfectly satisfactory. Organisations are at liberty to provide different equipment, to specify different tests, or to inspect equipment in a manner or at intervals assessed as appropriate to particular circumstances, provided that these alternatives are based on sound design or reasoning and that the outcome of worker safety is not prejudiced.

Both Arboriculture Australia Ltd and the New Zealand Arboricultural Association encourage any worker in any industry to conduct annual continued education and training to grow their competency in specific tasks and ensure they have appropriate training in the task being conducted prior to commencing any work.

The following diagram outlines the framework into which this MIS fits:



This MIS does not substitute for, or override, any legislation or regulation enacted by jurisdictional regulators or safety rules implemented by organisations. As depicted above, it is merely a guiding tool within the system.

Arboriculture Australia Ltd and the New Zealand Arboricultural Association will monitor the use and impact of these MIS and, consequently, may review and amend as the industry continues to evolve.

It is not the responsibility of Arboriculture Australia Ltd or of the New Zealand Arboricultural Association to notify users of these documents when reviews and reprints occur.

Using the MIS in training and assessment

This document provides information that can be used to assist students/learners in gaining knowledge and understanding industry terminology and norms. Learning and practising skill components must be conducted under the supervision of a competent person or trainer. Do not attempt to practice any of the techniques described in this document without the supervision of a competent practitioner.

In Australia

A key outcome for the production of national MIS documents is their use to support training aligned to the units of competency from the Australian AHC Agriculture, Horticulture, Conservation and Land Management Training Package, in particular the arboricultural industry sector-specific units of competency.

The MIS for each work task defines an industry consensus of the benchmark of competence in a work task. Therefore, it is an assessment requirement for each unit of competency that the performance criteria, performance evidence and knowledge evidence demonstrated by the candidate is **at least** to the level described in the MIS for that work task.

Where units of competency are not specific in their description of the industry techniques or benchmark of ability expected of holders of that unit, RTOs should use the relevant MIS document as a supplementary guide for industry expectations when conducting training or designing assessment instruments.

This does not mean that techniques or equipment not described in the relevant MIS should not be taught or assessed. There are many ways to appropriately complete each task and some methods and equipment may be more advanced than those in this document.

In New Zealand

A key outcome for the production of national MIS documents is their use to support training and education towards the New Zealand Certificates in Horticulture Services (Arboriculture) and Arboriculture. These Certificates (Levels 3 to 5) are designed to provide the arboriculture industry with individuals who have the technical skills and knowledge to safely undertake and manage arboriculture operations to maximise effectiveness.

The MIS for each work task defines an industry consensus of the benchmark of competence in a work task. The level at which the work task is assessed will reflect the New Zealand Qualification Authority (NZQA) Level, the Strategic Purpose of the qualification and the corresponding Educational and Employment Pathway. Depending on the relevant Graduate Profile, work tasks described in the MIS may address the content of more than one qualification and may progress more than one Education Pathway.

This does not mean that techniques or equipment not described in the relevant MIS should not be taught or assessed. There are many ways to appropriately complete each task and some methods and equipment may be more advanced than those in this document.

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Over time, changes in Australian and New Zealand Standards, industry standards and legislative requirements, as well as technological advances and other factors relevant to the information contained herein may affect the accuracy of the information contained in this document. Accordingly, caution should be exercised in relation to the use of the information in this document.

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